EXHIBIT 1

[redacted]

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

VIASAT, INC., *Plaintiff,* v. INTELLECTUAL VENTURES I LLC and INTELLECTUAL VENTURES II LLC, *Defendants.*	C.A. No. 1:25-cv-00056-CFC

<u>DECLARATORY JUDGMENT DEFENDANTS' PRELIMINARY INFRINGEMENT CONTENTIONS</u>

Declaratory Judgment Defendants Intellectual Ventures I LLC and Intellectual Ventures II LLC (collectively "DJ Defendants" or "IV"), by and through their attorneys of record, provide the following Preliminary Infringement Contentions to Declaratory Judgment Plaintiff Viasat, Inc. ("DJ Plaintiff" or "Viasat").

As stated in the accompanying charts (Exhibits 1 and 2), on information and belief, Viasat IFC systems in the past and presently infringe certain claims of U.S. Patent Nos. 7,324,469 and 8,027,326 (collectively, the "Patents-in-Suit") directly and indirectly based upon IV's research and analysis to date, without the benefit of sufficient discovery from Viasat.

[redacted]

For each asserted patent, IV identifies the Viasat IFC products of which it is currently aware in each of the accompanying charts (Exhibits 1 and 2). The identification is based on IV's research and analysis to date, without the benefit of sufficient discovery from DJ Plaintiff. IV reserves the right to add, delete, substitute or otherwise amend its list of accused instrumentalities based on discovery or other circumstances.

IV asserts that Viasat directly and indirectly infringes through the IFC products it provides in aircraft, vehicles, and nautical areas by making, using, offering for sale, and/or selling, or importing into the United States the IFC systems and services. To the extent that DJ Plaintiff alleges that one or more limitations of the asserted claims are not literally found in the accused instrumentalities, IV alleges that such limitations are found in or practiced by the accused instrumentalities under the doctrine of equivalents. Any differences alleged to exist between any of the asserted claims and any of the accused instrumentalities are insubstantial and that each accused instrumentality also meets each limitation under the doctrine of equivalents as the identified features of the accused instrumentality performs substantially the same function in substantially the same way to achieve substantially the same result as the corresponding claim limitation. IV reserves the right to assert infringement solely under the doctrine of equivalents with respect to any particular claim element(s), if warranted by discovery, further analysis, and/or claim constructions in this case.

[redacted]

IV further asserts that DJ Plaintiff has indirectly infringed and continues to indirectly infringe by actively inducing and contributing to infringement of one or more of the claims of each of the Patents-in-Suit through the accused instrumentalities as described in the accompanying charts. IV also asserts that these third parties directly infringe at least one or more of the claims of each of the Patents-in-Suit through the use of, implementation of, and/or integration with one or more of the accused instrumentalities.

For example, DJ Plaintiff has actively induced infringement by encouraging the use of the accused instrumentalities in ways that infringe each asserted claim. DJ Plaintiff knew or should have known that such encouragement would induce infringement. DJ Plaintiff has taken active steps with the specific intent to encourage and cause others to use each accused instrumentality in ways that infringe each asserted claim. Such active steps by DJ Plaintiff with specific intent to induce infringement have included, among other things, advertising, promoting, marketing, making available for use, offering to sell, and/or selling the accused instrumentalities to others; encouraging and influencing others to import, offer to sell, and/or sell the accused instrumentalities; directing and instructing others to use the accused instrumentalities in infringing ways; and by providing the accused instrumentalities to others. DJ Plaintiff has performed the aforementioned active steps with the knowledge

[redacted]

of the Patents-in-Suit at least as of the date when the Complaint was filed. DJ Plaintiff has known or should have known that the acts it has induced constitute infringement.

Further, the accused instrumentalities are known by DJ Plaintiff to be especially made or especially adapted for use to infringe the Patents-in-Suit and are not staple articles or commodity of commerce suitable for substantial non-infringing uses. DJ Plaintiff contributes to the infringement of the Patents-in-Suit by making available for use, offering for sale, selling, and/or importing the accused instrumentalities to third parties, who use the accused instrumentalities and/or practice one or more claims of the Patents-in-Suit. Moreover, DJ Plaintiff has had knowledge of the Patents-in-Suit at least as of the filing of the Complaint.

IV provides these Charts based on the information presently available to it. Discovery in this case is ongoing, and IV explicitly reserves the right to further modify, amend, and/or supplement its infringement claim charts with additional or different infringement theories and/or additional or different evidence. Further, IV reserves the right to add, delete, substitute or otherwise amend its list of asserted claims based on discovery or other circumstances.

[redacted]

Scheduling Order 3(a) – Asserted Claims[1]

- ’469 Patent: claims 24-26; 28; 32.
- ’326 Patent: claims 1; 4; 18.

Scheduling Order 3(b) – Each Accused Apparatus/Product[2]

- ’469 Patent: Viasat In-Flight Connectivity Systems, incorporated in aircrafts, vehicles and boats. Southwest identified the following components as part of the IFC system: antenna, a server unit, a modem unit, and four wireless access points. Muhich Dep Tr. at 24:6-10. The identification of specific components is not public.
- ’326 Patent: Viasat Systems and Services support Wi-Fi 802.11 ac/abgn, such as the Viasat Select Router. The identification of specific components is not public.

Scheduling Order 3(c) – Claim Charts

- ’469 Patent: Attached hereto as Exhibit 1
- ’326 Patent: Attached hereto as Exhibit 2

[1] DJ Defendants have not asserted counterclaims at this time but provide this information in an abundance of caution.

[2] DJ Defendants have not asserted counterclaims at this time but provide this information in an abundance of caution.

[redacted]

Scheduling Order 3(d) – Identification of Direct and Indirect Infringement

- ’469 Patent: Indirect Infringement
  - On information and belief, based on our current understanding, Viasat, with knowledge at least since the time of filing the complaint, indirectly infringes the ’469 Patent by inducing its customers (Airlines, Vehicles, and Ships) to incorporate its technology and operate the ViaSat systems in an infringing manner. Its customers directly infringe through making, using, offering for sale, and selling the systems that that incorporate Viasat Systems and Services in aircraft and other vehicles. Viasat provides documentation, engineering and technical assistance that instructs its customers on how to incorporate and operate its systems. On information and belief, Viasat provides software and software updates to allow the system to operate in an infringing manner by carriers of the IFC systems and use through passengers and other third-parties. On information and belief, Viasat also indirectly infringes by contributorily infringing the ’469 Patent by selling, offering to sell, or importing the IFC components that are incorporated into the aircraft, vehicles, and ships who utilize the systems and derive revenue from them. These IFC systems have no substantial non-infringing uses.

[redacted]

- ’326 Patent: Direct/Indirect Infringement
    - On information and belief, the Viasat Systems and Services directly infringe the asserted claims of the ’326 Patent, either literally or under the doctrine of equivalents, through using, selling, offering for sale a router modem product in its IFC system that contains a Wi-Fi chip. In addition, Viasat directly infringes the ’326 Patent by testing the Viasat Systems and Services that contain the router/modem and Wi-Fi chip. On information and belief, Viasat, with knowledge at least since the time of filing the complaint, also indirectly infringes the ’326 Patent by inducing its customers to use Viasat Systems and Services in Aircraft and vehicles, and to allow passengers and users of the systems. Viasat provides instructions and documentation including design documents, engineering support, and tutorials to explain how to use the Viasat Systems and Services in an infringing manner. On information and belief, Viasat also indirectly infringes by contributorily infringing the ’326 Patent by selling, offering to sell, or importing components used in the Viasat Systems and Services that do not have substantial non-infringing uses.

[redacted]

Scheduling Order 3(f) – Priority Dates

- Each of the Asserted Claims of the '469 Patent is entitled to a priority date of no later than September 29, 2003.
- Each of the Asserted Claims of the '326 Patent is entitled to a priority date of no later than January 12, 2004.

Scheduling Order 3(g) – No Known Apparatus

- None.

Scheduling Order 3(h) – Damages Time Period

- November 2, 2018. The timing of first infringement is currently unknown and, in the possession, custody, and control of Viasat. The earlies date based on the filing of the complaint is provided.

Scheduling Order 3(i) – Willful Infringement Disclosure

- IV has not asserted counterclaims at this time and has not alleged willful infringement. We reserve the right to allege willful infringement should IV allege counterclaims.

[redacted]

Dated: June 12, 2025

Respectfully submitted,

FARNAN LLP

/s/ Brian E. Farnan

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CERTIFICATE OF SERVICE

I hereby certify that a true and correct copy of the foregoing instrument was served or delivered electronically, via email, to all counsel of record on this 12th day of June 2025.

/s/ Jonathan K. Waldrop
Jonathan K. Waldrop

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Exhibit 1 to
Intellectual Ventures I LLC's and Intellectual Ventures II LLC's
Amended Infringement Contentions

[redacted]

Infringement Claim Chart of
U.S. Patent No. 7,324,469 ("'469 Patent")

The Accused Systems and Services include without limitation Viasat systems and services that provide WiFi in its own and third party systems; all past, current, and future systems and services that operate in the same or substantially similar manner as the specifically identified systems and services; and all past, current, and future Viasat systems and services that have the same or substantially similar features as the specifically identified systems and services ("Example Viasat Systems and Services" or "Viasat Systems and Services").[1] [2]

On information and belief, based on our current understanding, Viasat, with knowledge at least since the time of filing the complaint, indirectly infringes the '469 Patent by inducing its customers (Airlines, Vehicles, and Ships) to incorporate its technology and operate the ViaSat systems in an infringing manner. Its customers directly infringe through making, using, offering for sale, and selling the systems that that incorporate Viasat Systems and Services in aircraft and other vehicles. Viasat provides documentation, engineering and technical assistance that instructs its customers on how to incorporate and operate its systems. On information and belief, Viasat provides software and software updates to allow the system to operate in an infringing manner by carriers of the IFC systems and use through passengers and other third-parties. On information and belief, Viasat also indirectly infringes by contributorily infringing the '469 Patent by selling, offering to sell, or importing the IFC components that are incorporated into the aircraft, vehicles, and ships who utilize the systems and derive revenue from them. These IFC systems have no substantial non-infringing uses.IV has requested additional discovery to further understand Viasat's System and Services. Viasat or third party code and system logic related to satellite-distributed internet access points ("hotspots") have been requested. This includes mechanisms for detecting user devices, initiating authentication portals, validating prepaid or credit card access credentials, and managing session durations. Both client-side and remote server-side logic involved in account verification, time tracking, and conditional access termination are of interest. Implementations used in aircraft, vehicle, and nautical environments—including those leveraging solar or AC-powered satellite links.

[redacted]

[2] The description of non-accused Viasat Systems and Services reflects language in license agreement(s). The language of those agreement(s) controls, to the extent there are any inconsistencies between the language in this chart and such agreement(s).

[redacted]

Consistent with the local rules of this Court, IV identifies satellite-based WiFi as used in the Viasat Systems and Offerings and used in third party systems as the Accused Instrumentality. Information regarding how specifically Viasat implements WiFi, including for which products and offerings, is generally not public. IV intends to obtain discovery regarding how WiFi is used and implemented in Viasat products and services and will update its infringement positions once this discovery is completed.

IV does not intend this exemplary claim chart to be limiting, and IV reserves its rights to pursue other accused instrumentalities, patent claims, evidence, and infringement arguments in this case. Discovery has yet to begin, and this case is still in its initial stages. Accordingly, IV reserves the right to amend and/or supplement these contentions to the full extent allowed by the Court, including but not limited to, incorporating additional information, claims, theories, and / or accused products.

[redacted]

On information and belief, the Viasat Systems and Services are used to provide WiFi in third party systems, such as airplanes and vehicles.

Wi-Fi and connectivity

Inflight Wi-Fi

Upgraded, high-speed Wi-Fi is available to buy on select domestic flights. Browse the internet, check emails and stream video services like Netflix, Hulu and HBO faster than ever before.

Source: https://www.aa.com/i18n/travel-info/experience/entertainment/wi-fi-and-connectivity.jsp.[3]

[3] All sources cited in this document were publicly accessible as of June 12, 2025, the service date of the Preliminary Infringement Contentions.

[redacted]

Viasat

Live Chat
Air: Inflight Wi-Fi portal choose Contact Us

Ground: https://inflight.viasat.com/AAL

Phone:
1-888-649-6711

The inflight Wi-Fi portal will display "Connected by Viasat"

Your credit card statement charges will appear as "VIASAT IN-FLIGHT WIFI 888-649-6711 CA"

Source: https://www.aa.com/i18n/travel-info/experience/entertainment/wi-fi-and-connectivity.jsp.

Give your passengers the flexibility and peace of mind to stay connected in the air, knowing they won't miss anything. They'll enjoy life, uninterrupted, and continue to catch the latest sports games, chat, email, and work just as they do on the ground. With a solution that can deliver broadband level speed, everyone stays connected, happy and engaged throughout their flight.

Our high-speed in-flight service also ensures your crew runs efficiently and on schedule with real-time updates that improve productivity and customer service.

Viasat's high-capacity satellite network provides the bandwidth that allows you to offer fast, content-rich broadband experiences for passengers. However many passengers connect, Viasat can deliver high-speed connection to each passenger and can provide a network that can scale to your demand. Today and tomorrow.

Source: https://www.viasat.com/content/dam/us-site/aviation/documents/565522_In-flight_Connectivity_011_aag.pdf.

[redacted]

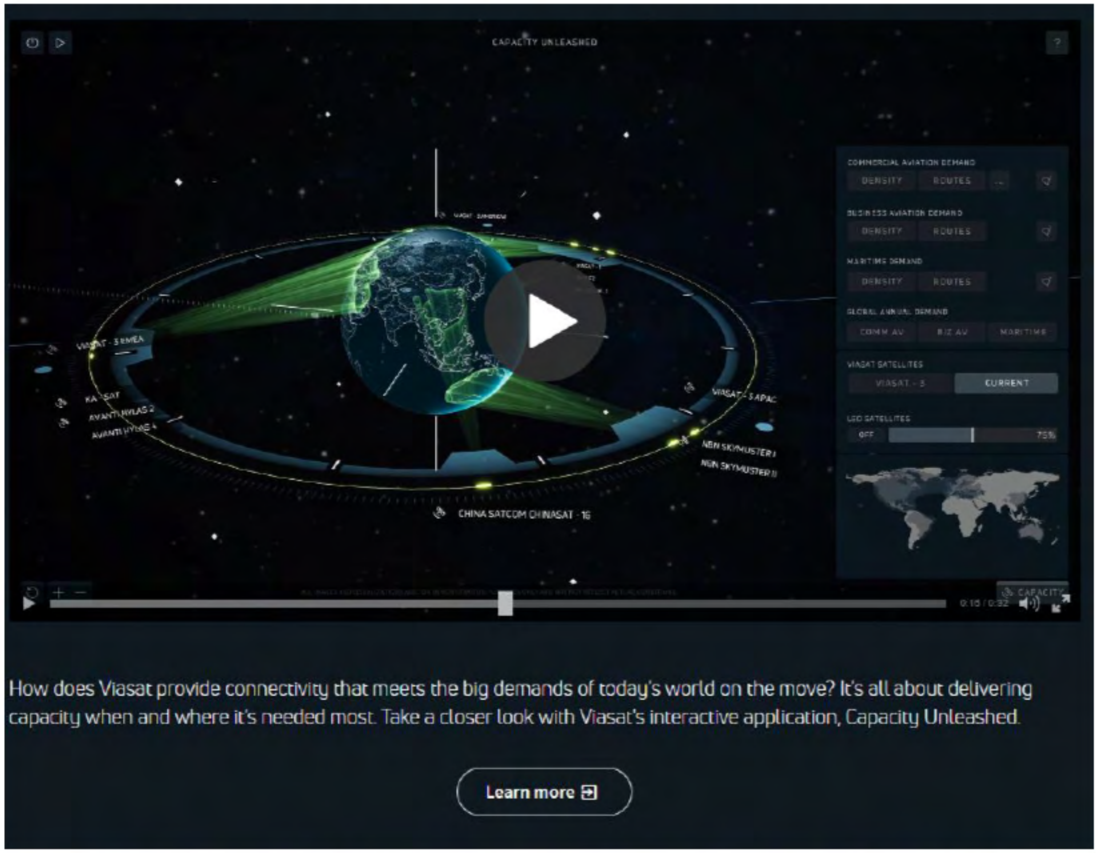
U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	**Example Viasat Systems and Services**
[24.pre] An Internet Hotspot comprising:	To the extent this preamble is limiting, on information and belief, the Viasat Systems and Services include an Internet Hotspot. For example, Viasat Systems and Services are incorporated into Aircraft and vehicles. On information and belief, Viasat has partnered with carriers and vehicle manufacturers to provide Wi-Fi connectivity.[4] Wi-Fi and connectivity  Inflight Wi-Fi Upgraded, high-speed Wi-Fi is available to buy on select domestic flights. Browse the internet, check emails and stream video services like Netflix, Hulu and HBO faster than ever before. Source: https://www.aa.com/i18n/travel-info/experience/entertainment/wi-fi-and-connectivity.jsp.

[4] During the deposition of Christopher Muhich, Southwest identified Viasat as one of multiple IFC providers, including Anuvu and Panasonic Avionics. Muhich Dep. Tr. at 34:6-10.

[redacted]

U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	**Example Viasat Systems and Services**
	Give your passengers the flexibility and peace of mind to stay connected in the air, knowing they won't miss anything. They'll enjoy life, uninterrupted, and continue to catch the latest sports games, chat, email, and work just as they do on the ground. With a solution that can deliver broadband level speed, everyone stays connected, happy and engaged throughout their flight. Our high-speed in-flight service also ensures your crew runs efficiently and on schedule with real-time updates that improve productivity and customer service. Viasat's high-capacity satellite network provides the bandwidth that allows you to offer fast, content-rich broadband experiences for passengers. However many passengers connect, Viasat can deliver high-speed connection to each passenger and can provide a network that can scale to your demand. Today and tomorrow. Source: https://www.viasat.com/content/dam/us-site/aviation/documents/565522_In-flight_Connectivity_011_aag.pdf.
[24.a] a satellite dish communicating with the Internet via one or more data links with a satellite;	On information and belief, the Viasat Systems and Services include a satellite dish communicating with the Internet via one or more data links with a satellite. On information and belief, the Viasat Systems and Services are integrated into its own or third party systems, such as and includes a satellite antenna mounted about the plane that communicates with the Internet using a satellite with a ground station. Source: https://www.viasat.com/aviation/business-aviation/viasat-ka/; Muhich Dep. Tr. at 19:21-21:12; 24:6-10.
[24.b] at least one router operatively coupled to the satellite dish;	On information and belief, the Viasat Systems and Services include at least one router operatively coupled to the satellite dish. On information and belief, the Viasat Systems and Services are integrated into its own or third party

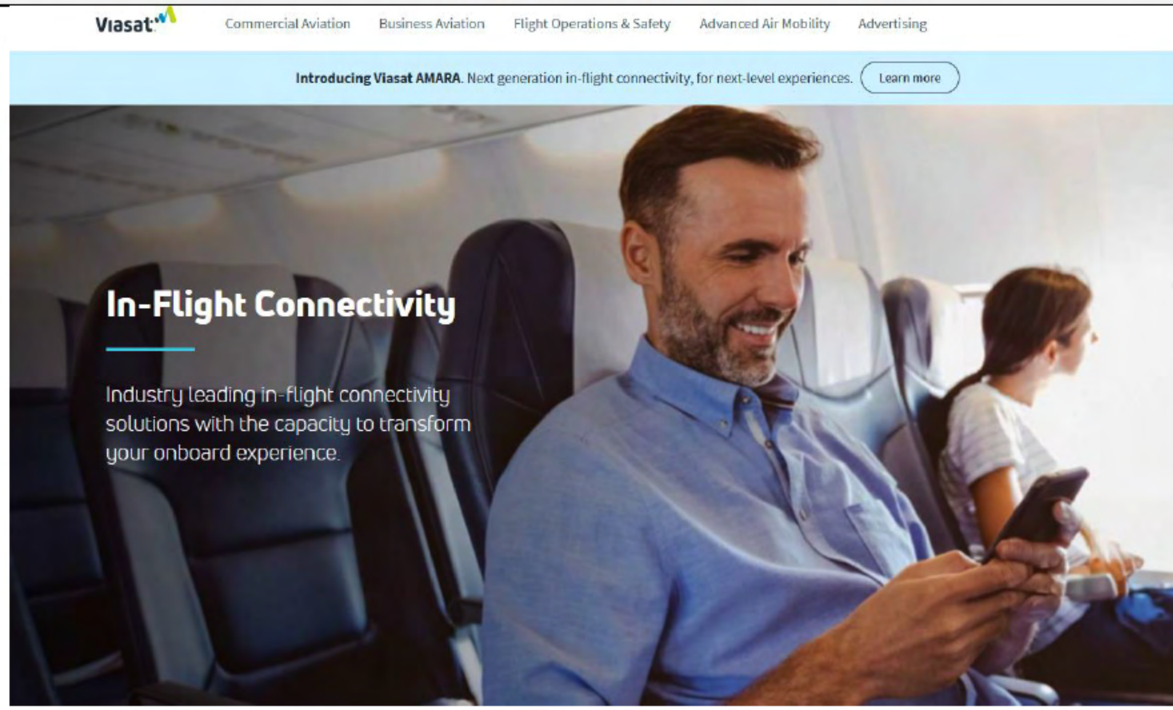
[redacted]

U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	**Example Viasat Systems and Services**
	systems, such as aircrafts, vehicles and boats. For example, aircraft are equipped with Viasat IFC systems that include a router that is connected to a satellite antenna mounted about the plane that communicates with the Internet using a satellite with a ground station.  Source: https://www.viasat.com/aviation/business-aviation/viasat-ka/; Muhich Dep. Tr. at 55:3-5.

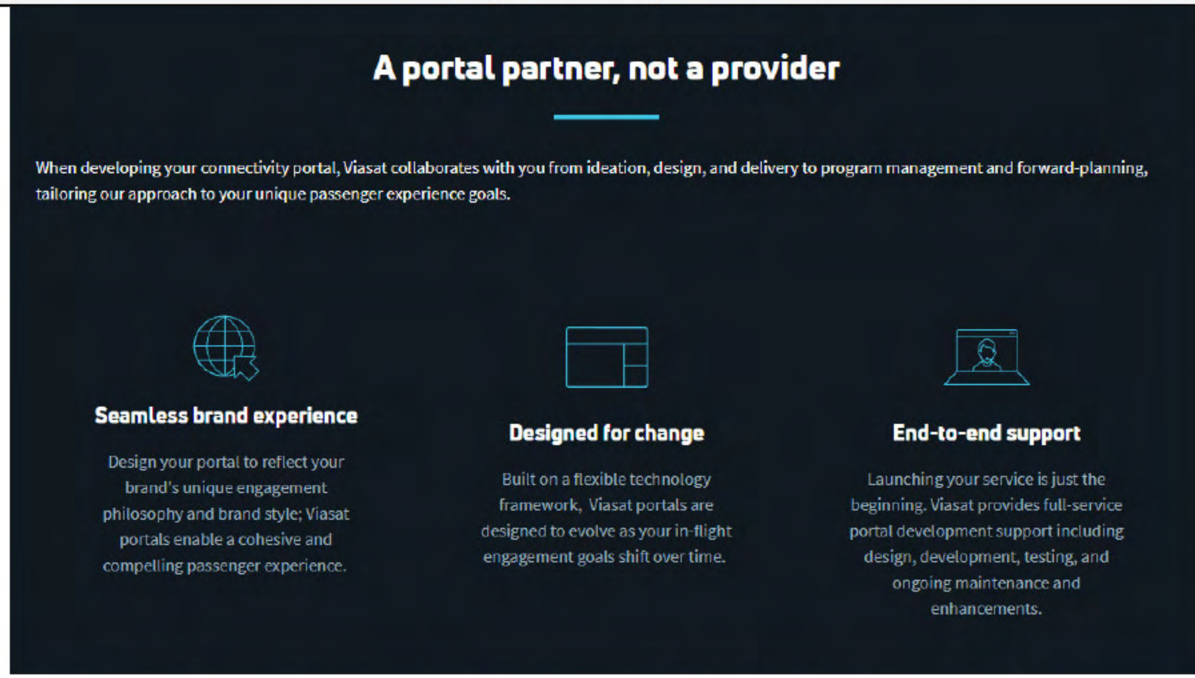
[redacted]

U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	**Example Viasat Systems and Services**
[24.c] a subscriber access unit operatively coupled between the satellite dish and the at least one router, the subscriber access unit being capable of authenticating a subscription account associated with a user prior to allowing the user access to the Internet; and	On information and belief, aircraft, vehicles and boats that utilize the Viasat systems include a subscriber access unit that is operatively coupled between the satellite dish and the at least one router, the subscriber access unit being capable of authenticating a subscription account associated with a user prior to allowing the user access to the Internet. On information and belief, aircraft, vehicles and boats that utilize the Viasat systems includes a satellite antenna, multiple WAPs, and an onboard server that hosts information passenger-focused services. Source: Muhich Dep. Tr. at 19:21-21:12; 24:6-10. On information and belief, the Viasat system is used in conjunction with the subscriber access unit. On information and belief, users that access Wi-Fi services are authenticated through a web portal to access in-flight Wi-Fi for example through a subscriber access unit. The authentication completes when the user enters their login credentials on the portal and the user is authenticated. The Wi-Fi is available to passengers and can be provided for free or upgraded, for a fee, to higher speeds.

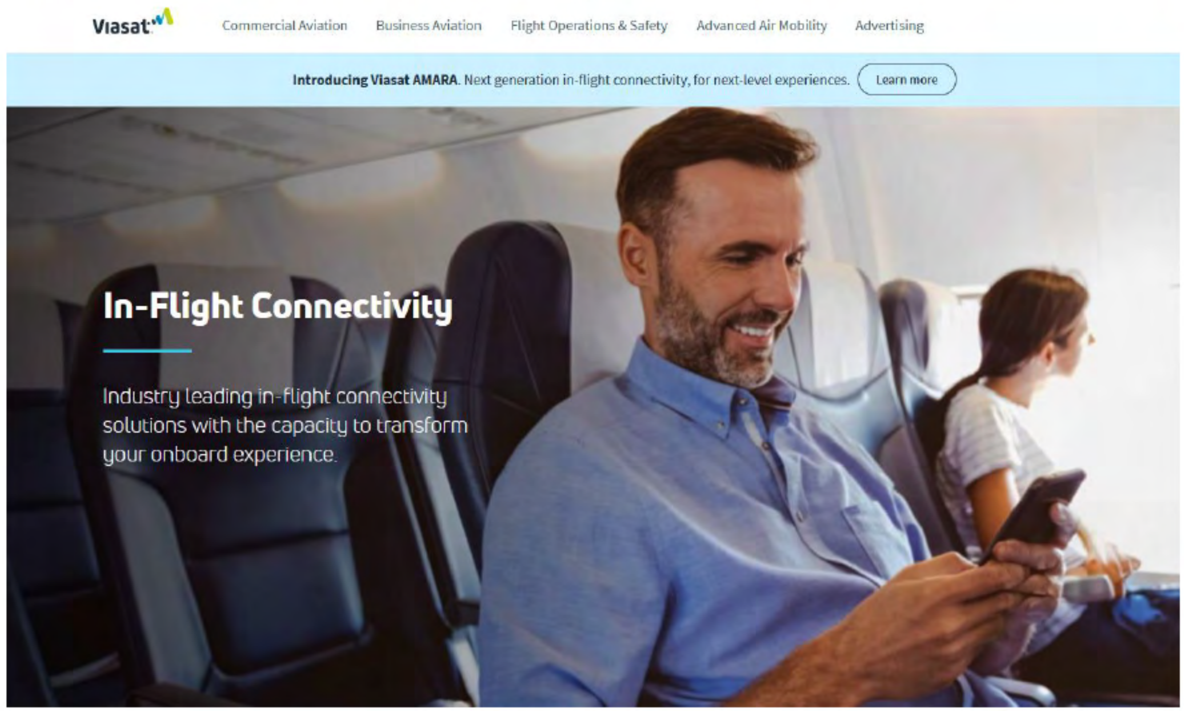
[redacted]

U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	**Example Viasat Systems and Services**
	 Source: https://www.viasat.com/aviation/commercial-aviation/in-flight-connectivity/

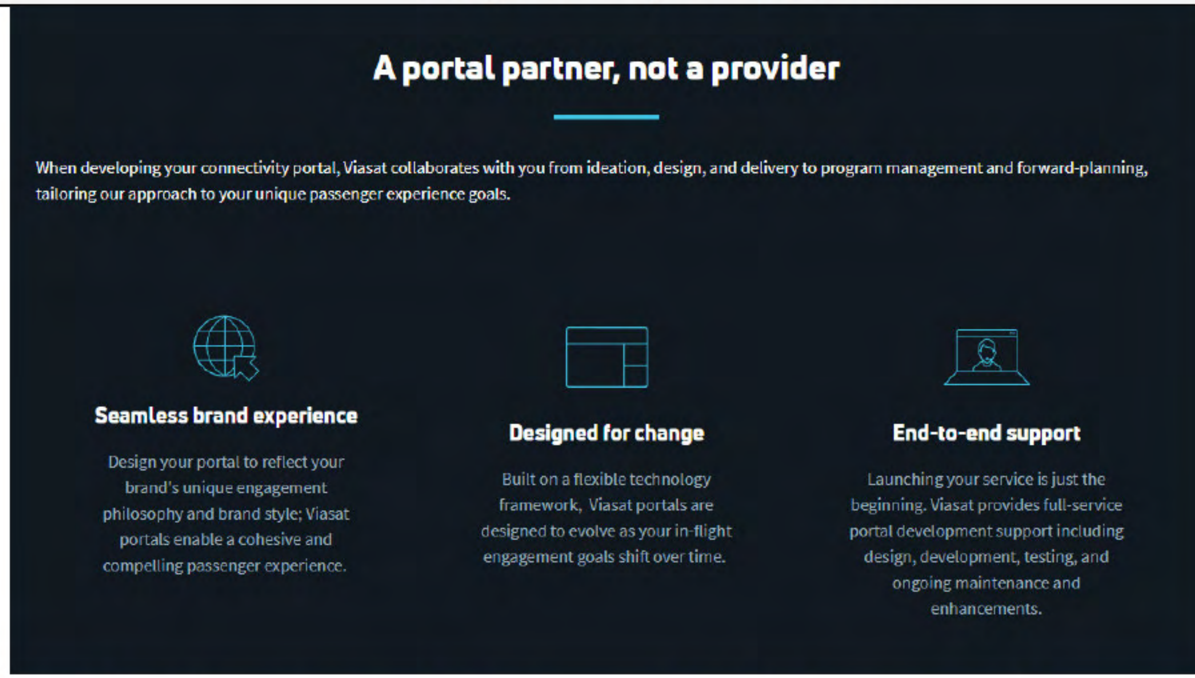
[redacted]

U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	Example Viasat Systems and Services
	 Source: https://www.viasat.com/aviation/commercial-aviation/passenger-portals/

[redacted]

U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	**Example Viasat Systems and Services**
[24.d] a web-ready device operatively coupled to the at least one router, the web-ready device having a browser application operating thereon for accessing the Internet;	On information and belief, aircraft, vehicles and boats that utilize the Viasat systems include a web-ready device operatively coupled to the at least one router, the web-read device having a browser application operating thereon for accessing the Internet. On information and belief, Viasat Systems and Services are incorporated into aircraft, vehicles and boats. The IFC systems enable access to onboard WiFi through seatback and/or user devices that include a browser application for Internet accessibility.  Source: https://www.viasat.com/aviation/commercial-aviation/in-flight-connectivity/

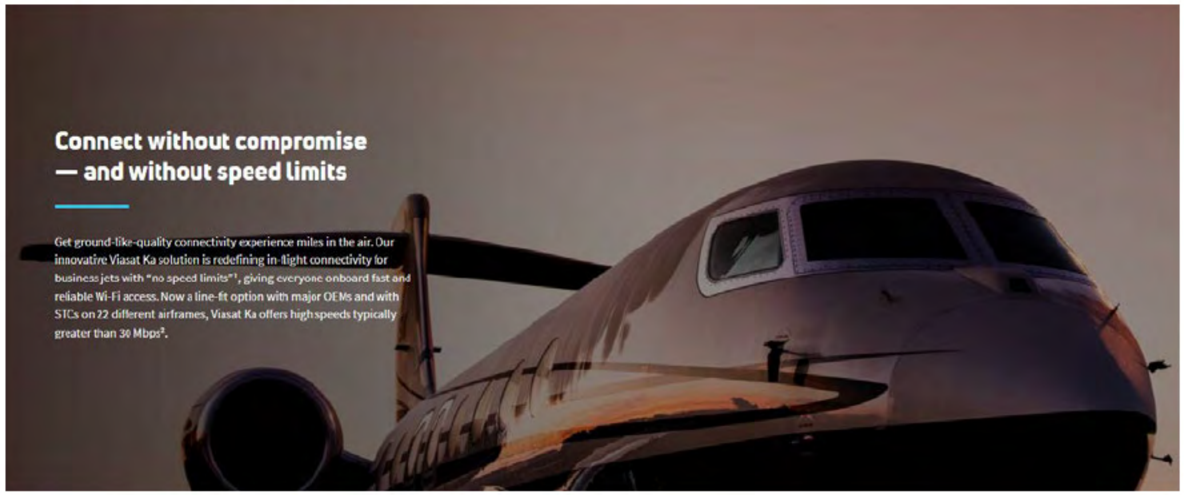
[redacted]

U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	**Example Viasat Systems and Services**
	 Source: https://www.viasat.com/aviation/commercial-aviation/passenger-portals/

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 7,324,469 (Claim 24)</th></tr>
<tr><th>Claim 24</th><th>Example Viasat Systems and Services</th></tr>
<tr><td>[24.e] wherein the satellite dish, at least one router and the subscriber access unit are located in a remote location a experiencing a relatively high volume of transient traffic;</td><td>On information and belief, the Viasat Systems and Services include a satellite dish, at least one router, and a subscriber access unit, where the satellite dish, at least one router and the subscriber access unit are located in a remote location a experiencing a relatively high volume of transient traffic.

On information and belief, the Viasat Systems and Services are integrated into larger systems and aircraft, vehicles and boats.



Source: https://www.viasat.com/aviation/business-aviation/viasat-ka/; Muhich Dep. Tr. at 19:21-21:12; 24:6-10.</td></tr>
<tr><td>[24.f] wherein the user may authenticate the subscription account and access the Internet at the remote location by establishing a data connection between the web-ready device and the router.</td><td>On information and belief, the Viasat Systems and Services IFC components facilitate WiFi and are used in conjunction with other components such that the user may authenticate the subscription account and access the Internet at the remote location by establishing a data connection between the web-ready device and the router.

On information and belief, aircraft providers and aircraft and vehicle passengers are able to authenticate themselves on the web portal to access in-flight Wi-Fi. The authentication completes when the user enters their login credentials on the portal.</td></tr>
</table>

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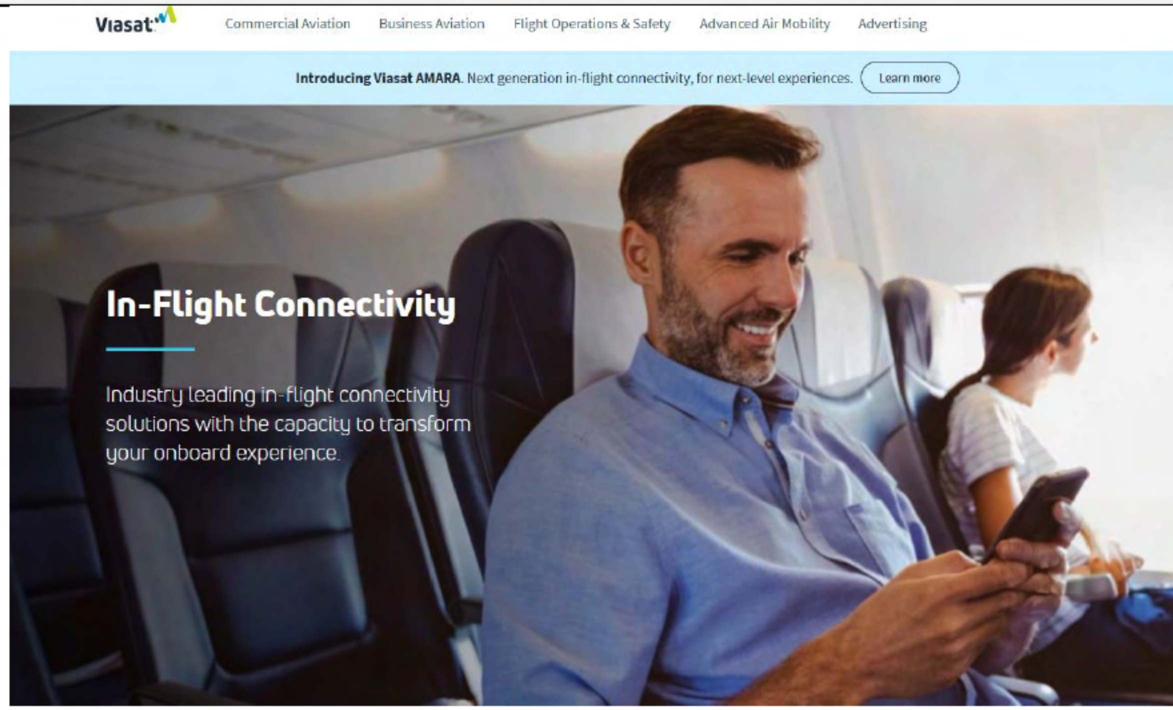
U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	**Example Viasat Systems and Services**
	 Source: https://www.viasat.com/aviation/commercial-aviation/in-flight-connectivity/

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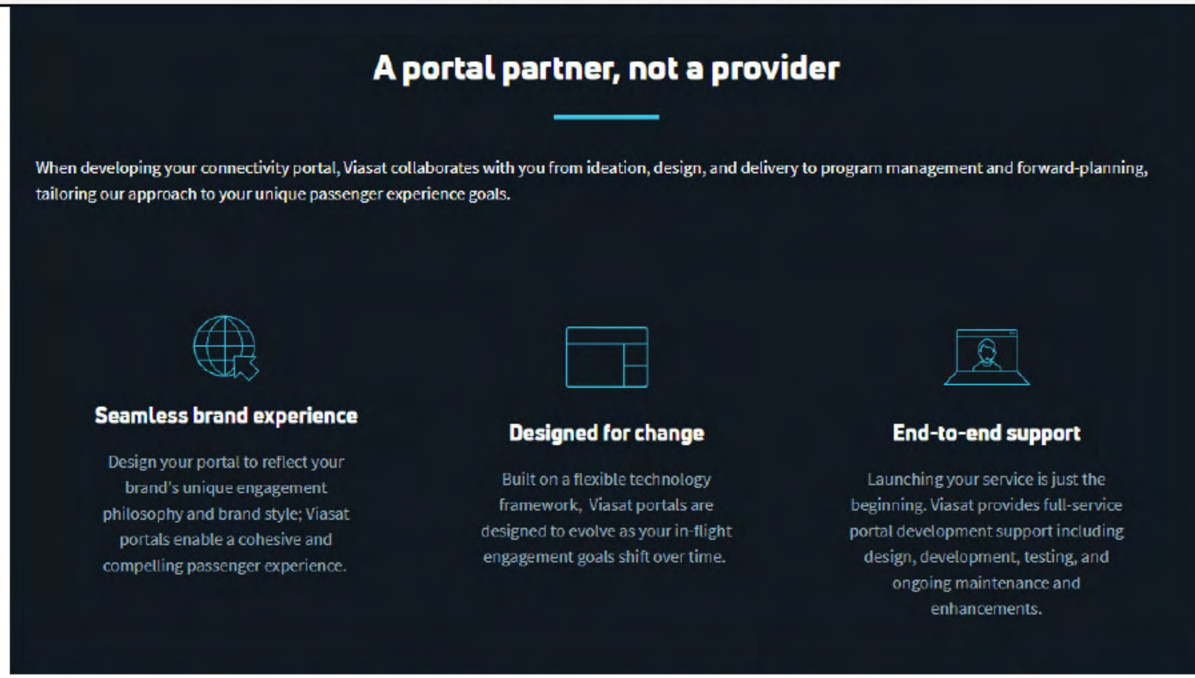
U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	**Example Viasat Systems and Services**
	 Source: https://www.viasat.com/aviation/commercial-aviation/passenger-portals/

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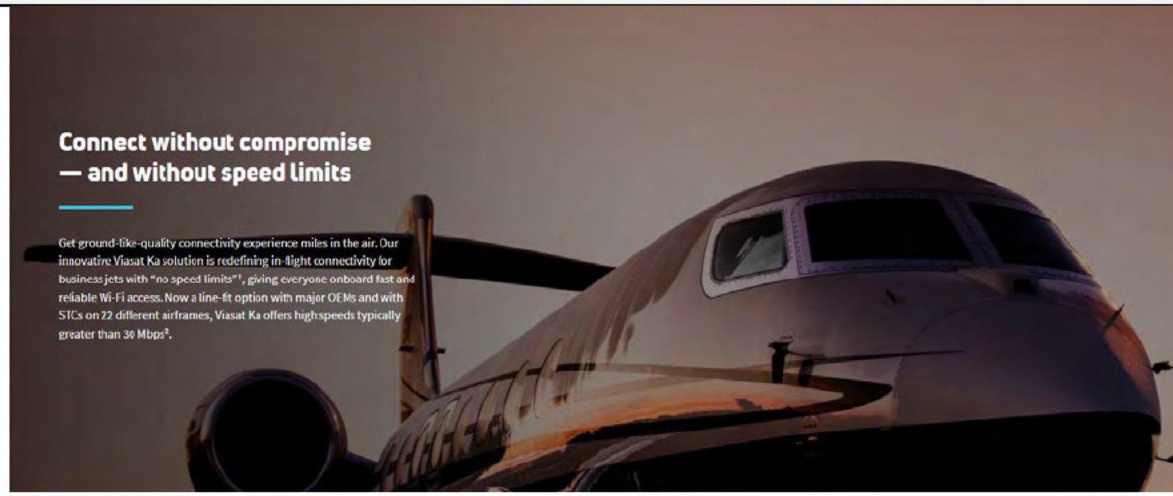
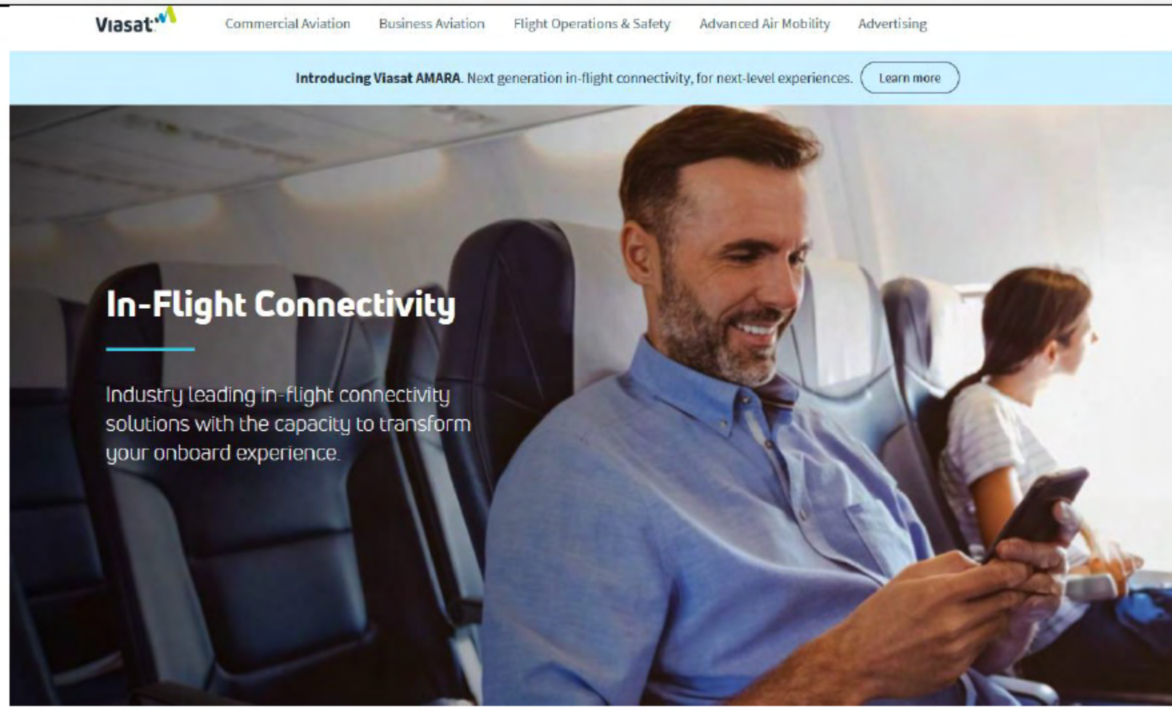
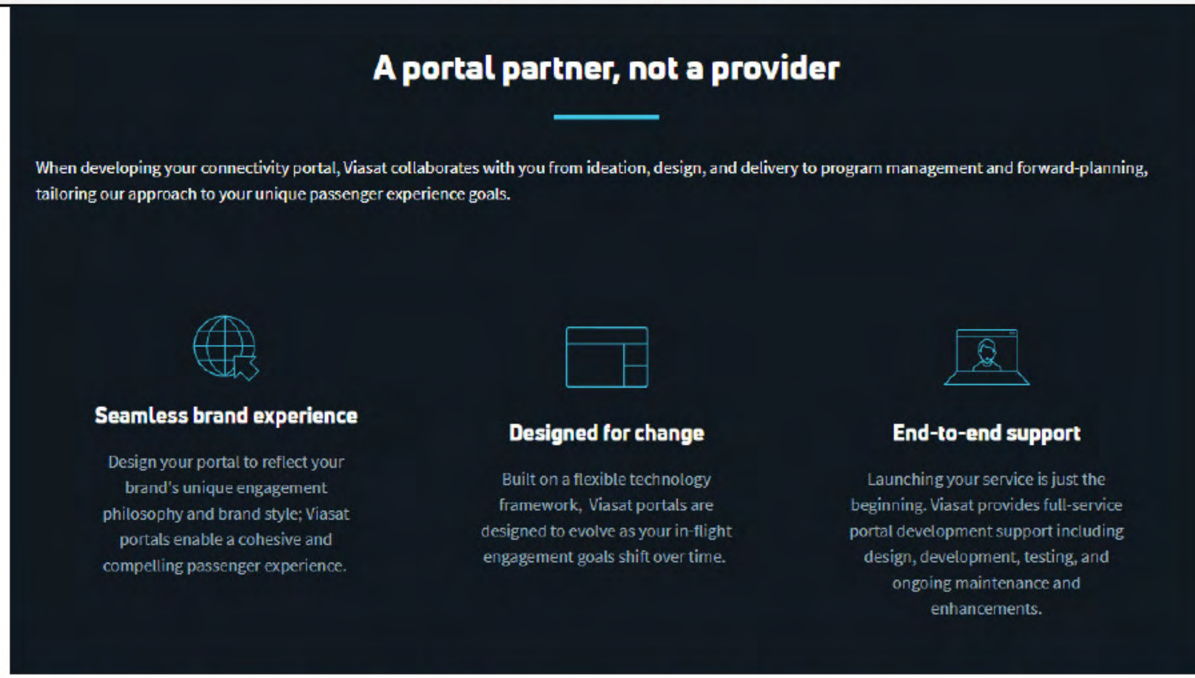
U.S. Patent No. 7,324,469 (Claim 24)	
Claim 24	**Example Viasat Systems and Services**
	 Source: https://www.viasat.com/aviation/business-aviation/viasat-ka/; Muhich Dep. Tr. at 19:21-21:12; 24:6-10.

U.S. Patent No. 7,324,469 (Claim 25)	
Claim 25	**Example Viasat Systems and Services**
[25] The Internet Hotspot of claim 24, wherein the data connection is one of a wired data connection and a wireless data connection.	On information and belief, the Viasat Systems and Services include an Internet Hotspot as recited in claim 24. *See* claim 24. On information and belief, the Viasat Systems and Services further include the data connection that is one of a wired data connection and a wireless data connection. As described elsewhere in this claim chart, the Viasat Systems and Services are integrated into aircraft, vehicles and boats that enables customers and its customers' customers to access data including flight tracker, text, video, and other content that is available over a wireless connection.

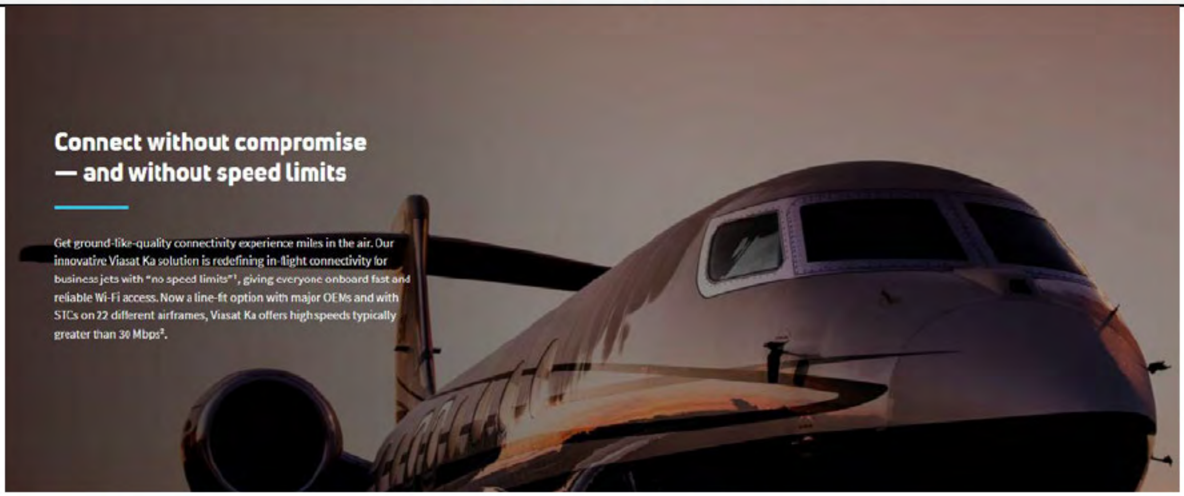
[redacted]

U.S. Patent No. 7,324,469 (Claim 25)	
Claim 25	**Example Viasat Systems and Services**
	 Source: https://www.viasat.com/aviation/commercial-aviation/in-flight-connectivity/

[redacted]

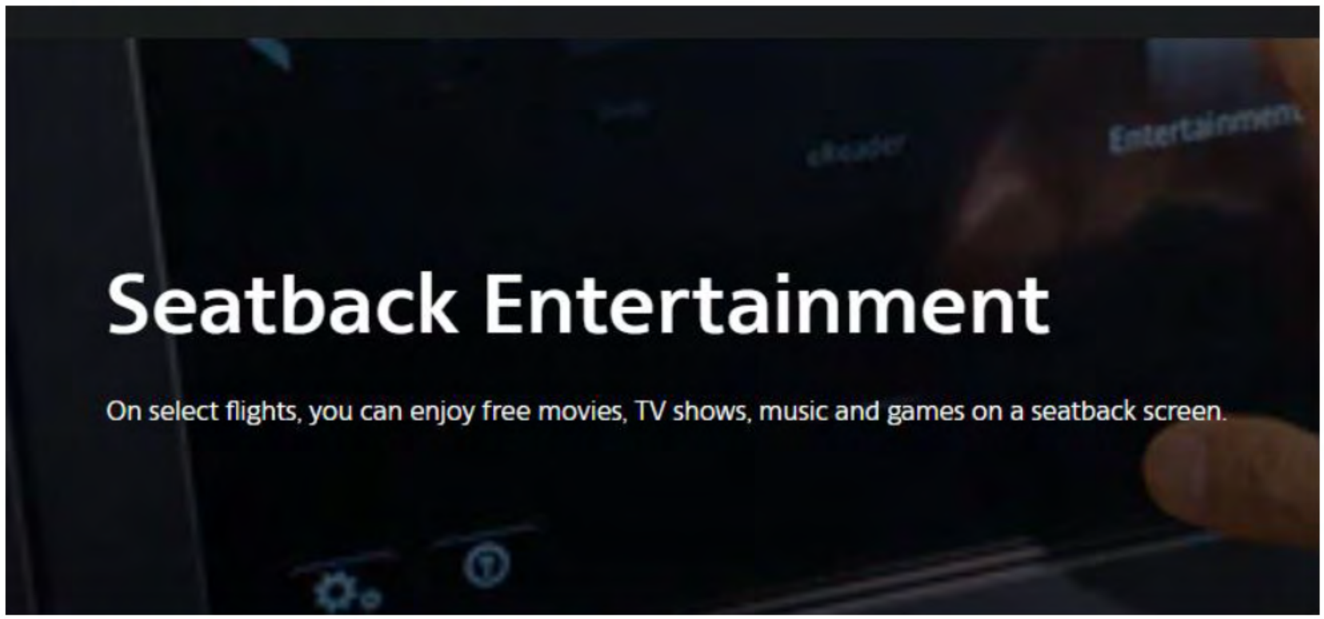
U.S. Patent No. 7,324,469 (Claim 25)	
Claim 25	**Example Viasat Systems and Services**
	 Source: https://www.viasat.com/aviation/commercial-aviation/passenger-portals/

[redacted]

U.S. Patent No. 7,324,469 (Claim 25)	
Claim 25	**Example Viasat Systems and Services**
	 Source: https://www.viasat.com/aviation/business-aviation/viasat-ka/

U.S. Patent No. 7,324,469 (Claim 26)	
Claim 26	**Example Viasat Systems and Services**
[26] The Internet Hotspot of claim 24, wherein a plurality of users may access the Internet simultaneously at the remote location by respectively establishing data connections with the router via their web-ready devices.	On information and belief, the Viasat Systems and Services facilitate the use of an Internet Hotspot as recited in claim 24. *See* claim 24. On information and belief, the Viasat Systems and Services further facilitate a plurality of users who may access the Internet simultaneously at the remote location by respectively establishing data connections with the router via their web-ready devices. As described elsewhere in this claim chart, the Viasat Systems and Services are integrated into aircraft, vehicles and boats. For example, for WiFi-enabled aircraft, American offers Internet service that enables its customers to access data including flight tracker, text, video, and other content that is available over a wireless connection. On information and belief, multiple customers can access the Internet simultaneously during a flight, in part through a router.

[redacted]

U.S. Patent No. 7,324,469 (Claim 26)	
Claim 26	**Example Viasat Systems and Services**
	What devices can I use to access free entertainment? You can access free entertainment on Apple iOS, Android, macOS and Windows. The browsers we support are Chrome, Safari and Edge. Source: https://support.aainflight.com/.  Source: https://entertainment.aa.com/en/how-to-watch.

[redacted]

U.S. Patent No. 7,324,469 (Claim 28)	
Claim 28	**Example Viasat Systems and Services**
[28] The Internet Hotspot of claim 26, wherein the data connections include wireless data connections.	On information and belief, the Viasat Systems and Services facilitate the use of an Internet Hotspot as recited in claim 26. *See* claim 26. On information and belief, the Viasat Systems and Services further utilize a data connections that include wireless data connections. As described elsewhere in this claim chart, the Viasat Systems and Services are incorporated into aircraft, vehicles, and boats. For example, WiFi-enabled aircraft, American offers Internet service that enables its customers to access data including flight tracker, text, video, and other content that is available over a wireless connection. Wi-Fi and connectivity  Inflight Wi-Fi Upgraded, high-speed Wi-Fi is available to buy on select domestic flights. Browse the internet, check emails and stream video services like Netflix, faster than ever before. Source: https://www.aa.com/i18n/travel-info/experience/entertainment/wi-fi-and-connectivity.jsp. *See also* claim 24.

[redacted]

U.S. Patent No. 7,324,469 (Claim 32)	
Claim 32	**Example Viasat Systems and Services**
[32] The Internet Hotspot of claim 25, wherein the wireless connection is one of an 802.11a wireless area network, an 802.11b wireless area network, an 802.11g wireless area network, and an 802.11n wireless area network.	On information and belief, the Viasat Systems and Services include an Internet Hotspot as recited in claim 32. *See* claim 32. On information and belief, the Viasat Systems and Services further include the wireless connection that is one of an 802.11a wireless area network, an 802.11b wireless area network, an 802.11g wireless area network, and an 802.11n wireless area network. For example, on information and belief, the specification for version 802.11n was released in approximately 2009. Source: https://www.techtarget.com/searchmobilecomputing/definition/80211n. On information and belief, devices that support newer WiFi standards are backwards compatible with earlier standards, such as version 802.11n. **Wi-Fi 6 Compatibility** When you are considering upgrading your routers, it's a good idea to factor in Wi-Fi 6 compatibility with your older equipment and devices. Wi-Fi 6-compatible devices must work with other equipment. Is Wi-Fi 6 backward compatible, and will current devices work with it? The good news: Wi-Fi 6 routers are completely backward compatible with all older Wi-Fi devices that support earlier versions, including 802.11 ac/n/g/b/a. Source: https://www.digi.com/blog/post/wi-fi-6-compatible-devices-and-their-use-cases. On information and belief, Viasat facilitates the use of Internet service include wireless connections. *See* claims 25, 28. On information and belief, Viasat's Internet service including wireless connections support 802.11n wireless networks, including end user devices that are compatible with 802.11n and use that network for Internet connectivity. *See* claim 34. *See also*: Source: https://www.techtarget.com/searchmobilecomputing/definition/80211n. Source: https://www.digi.com/blog/post/wi-fi-6-compatible-devices-and-their-use-cases.

[redacted]

Exhibit 2 to
Intellectual Ventures I LLC's and Intellectual Ventures II LLC's
Amended Infringement Contentions

[redacted]

Infringement Claim Chart of
U.S. Patent No. 8,027,326 ("'326 Patent")

The Accused Systems and Services include without limitation Viasat systems and services that provide Wi-Fi Access Points that support at least IEEE 802.11n and/or 802.11ac; all past, current, and future systems and services that operate in the same or substantially similar manner as the specifically identified systems and services; and all past, current, and future Viasat systems and services that have the same or substantially similar features as the specifically identified systems and services ("Example Viasat Systems and Services" or "Viasat Systems and Services").[1] [2]

o On information and belief, the Viasat Systems and Services directly infringe the asserted claims of the '326 Patent, either literally or under the doctrine of equivalents, through using, selling, offering for sale a router modem product in its IFC system that contains a Wi-Fi chip. In addition, Viasat directly infringes the '326 Patent by testing the Viasat Systems and Services that contain the router/modem and Wi-Fi chip. On information and belief, Viasat, with knowledge at least since the time of filing the complaint, also indirectly infringes the '326 Patent by inducing its customers to use Viasat Systems and Services in Aircraft and vehicles, and to allow passengers and users of the systems. Viasat provides instructions and documentation including design documents, engineering support, and tutorials to explain how to use the Viasat Systems and Services in an infringing manner. On information and belief, Viasat also indirectly infringes by contributorily infringing the '326 Patent by selling, offering to sell, or importing components used in the Viasat Systems and Services that do not have substantial non-infringing uses. IV has requested additional discovery to further understand Viasat's Systems and Services. Viasat or third party code and technical materials related to onboard wireless LAN systems that employ multi-channel or wideband techniques to increase throughput. This includes any dual-channel transmission or reception logic, adaptive anti-aliasing filters, and firmware or drivers responsible for managing spectrum overlap or mitigating adjacent-channel interference. Functionality that enables expanded bandwidth wireless connectivity using legacy or modified single-channel radio components.

[redacted]

[2] The description of non-accused Viasat Systems and Services reflects language in license agreement(s). The language of those agreement(s) controls, to the extent there are any inconsistencies between the language in this chart and such agreement(s).

[redacted]

Consistent with the local rules of this Court, IV identifies systems and services that provide Wi-Fi Access Points that support at least IEEE 802.11n and/or 802.11ac, as used in Viasat's systems and offerings, as the Accused Instrumentality. Information regarding how specifically Viasat implements WiFi, including for which products and offerings, is generally not public. IV intends to obtain discovery regarding how WiFi is used and implemented in Viasat products and services and will update its infringement positions once this discovery is completed.

IV does not intend this exemplary claim chart to be limiting, and IV reserves its rights to pursue other accused instrumentalities, patent claims, evidence, and infringement arguments in this case. Discovery has yet to begin, and this case is still in its initial stages. Accordingly, IV reserves the right to amend and/or supplement these contentions to the full extent allowed by the Court, including but not limited to, incorporating additional information, claims, theories, and / or accused products.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
[1.pre] A method for increasing data rates and data throughput in a network, the method comprising:	To the extent this preamble is limiting, on information and belief, the Viasat Systems and Services practice a method for increasing data rates and data throughput in a network. On information and belief, the Viasat Systems and Services support Wi-Fi 802.11 ac/abgn, such as the Viasat Select Router.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	The Gen-2 equipment includes upgrades to the following: • **Antenna:** ViaSat's Gen-2 antenna supports the full Ka-band spectrum defined by the International Telecommunication Union (ITU), doubling useable satellite capacity and enabling the full range of capabilities on ViaSat's satellites. An upgraded Gen-2 Antenna Power Supply is designed to make use of ARINC 791 provisions for simple installation. • **Radome:** ViaSat optimized its Gen-2 radome and ARINC 791-compatible mounting plate for reduced weight and minimal signal distortion, enabling full performance on ViaSat's satellites while reducing fuel consumption. • **Modem:** ViaSat's Gen-2 modem is capable of supporting throughput levels of up to 1 Gigabit per second (Gbps), allowing airlines to make the most of the advanced capabilities expected from ViaSat's current and next-generation satellite platforms. • **Wireless Access Points (WAPs):** ViaSat's 802.11ac Wave 2 WAPs deliver higher speeds from the modem to each connected device on the aircraft by removing potential bottlenecks caused by the cabin design. • **On-Board Server:** ViaSat is enabling airlines to host more in-flight crew, ground crew and passenger-focused applications with its open platform server. ViaSat's future focused platform is backed by a powerful quad-core Intel CPU and 30 terabytes (TB) of solid-state storage, far exceeding the capabilities of other in-flight servers deployed today.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Source: https://investors.viasat.com/news-releases/news-release-details/viasat-unveils-second-generation-mobility-equipment-deliver.[3] Viasat Select Router Redefining the in-flight connectivity experience The Viasat Select Router, coupled with Viasat's latest generation satellite terminal, delivers a fully managed internet connectivity network inside the cabin that promises to deliver maximum speed and capabilities from Viasat's high-capacity satellite network. Source: https://www.viasat.com/content/dam/us-site/aviation/documents/Viasat_Select_Router-datasheet.pdf.

[3] All sources cited in this document were publicly accessible as of June 12, 2025, the service date of the Preliminary Infringement Contentions.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Multi-link connections The Viasat Select Router ("VSR") is a fully featured cabin connectivity management device that integrates the Viasat connectivity service with other available cabin connectivity on the aircraft. User traffic is routed automatically over the best available network and in the event of a service disruption, an alternate service is automatically selected to ensure continuous internet access. Every VSR is equipped with an integral cellular modem that enables near global 4G LTE data service while the aircraft is on the ground. The data service can be used by passengers or crew, and is available to Viasat's technical support team for remote access to assist with equipment configuration, software updates, and other troubleshooting support, while the aircraft remains in the hangar. The router incorporates an 802.11ac Wi-Fi access point for easy in-cabin wireless connectivity for passengers, crew and ground operations. Additional antennas can be added to ensure optimal signal strength inside the cabin as necessary. Source: https://www.viasat.com/content/dam/us-site/aviation/documents/Viasat_Select_Router-datasheet.pdf.

SPECIFICATIONS

Size	1.75 in. H × 7.8 in. W × 5.5 in. D	**Storage**	1 TB (OS and applications)
Weight	3.9 lbs	**Ethernet Ports**	› 5 x 10/100/1000 bps Ethernet › 1 x 10/100/1000 bps Ethernet › 1 x 10/100/1000 bps Ethernet
Voltage	28VDC with 200ms Hold-up		
Power	20W(typical); 30W (max)	**ARINC 429**	2x Rx Channels / 1x Tx Channel
Environment	Qualified to DO-160G	**Cellular Modem**	Integrated Global coverage 4G/ 2x mini SIMs; 2x RF QMA conne
Processor	Intel E3845 4 Core processor, 1.5GHz	**Wi-Fi**	802.11 ac/abgn; 3x RF QMA con

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Source: https://www.viasat.com/content/dam/us-site/aviation/documents/Viasat_Select_Router-datasheet.pdf. **IEEE 802.11n™, or Wi-Fi 4**, was introduced in 2009 to support the 2.4 GHz and 5GHz freque Mbit/s data rates, multiple channels within each frequency band, and other features. IEEE 8 enabled the use of WLAN networks in place of wired networks, a significant feature enablin reduced operational costs for end users and IT organizations. **IEEE 802.11ac™, or Wi-Fi 5**, was introduced in 2013 to support data rates at up to 3.5 Gbit/s, with still-great channels, better modulation, and other features. It was the first Wi-Fi standard to enable the use of multipl technology so that multiple antennas could be used on both sending and receiving devices to reduce error Source: https://standards.ieee.org/beyond-standards/the-evolution-of-wi-fi-technology-and-standards/. On information and belief, by bonding two 20 MHz channels together, the IEEE 802.11n-2009 standard enables 40 MHz capable high throughput (HT) operation, which can support high data rates up to 600 Mb/s.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	3A. Definitions specific to IEEE 802.11 The following terms and definitions are specific to this standard and are not appropriate for inclusion in the *IEEE Standards Dictionary: Glossary of Terms & Definitions*.[1] **3A.1 20 MHz basic service set (BSS):** A BSS in which the Secondary Channel Offset field is set to SCN. **3A.2 20 MHz high-throughput (HT):** A Clause 20 transmission using FORMAT=HT_MF or HT_GF and CH_BANDWIDTH=HT_CBW20. **3A.3 20 MHz mask physical layer convergence procedure (PLCP) protocol data unit (PPDU):** A Clause 17 PPDU, a Clause 19 orthogonal frequency division multiplexing (OFDM) PPDU, or a Clause 20 20 MHz high-throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH set to HT_CBW20 and the CH_OFFSET parameter set to CH_OFF_20. The PPDU is transmitted using a 20 MHz transmit spectral mask defined in Clause 17, Clause 19, or Clause 20, respectively. **3A.4 20 MHz physical layer convergence procedure (PLCP) protocol data unit (PPDU):** A Clause 15 PPDU, Clause 17 PPDU, Clause 18 PPDU, Clause 19 orthogonal frequency division multiplexing (OFDM) PPDU, or Clause 20 20 MHz high-throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH set to HT_CBW20.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	3A.5 20/40 MHz basic service set (BSS): A BSS in which the supported channel width of the access point (AP) or independent BSS (IBSS) dynamic frequency selection (DFS) owner (IDO) station (STA) is 20 MHz and 40 MHz (Channel Width field is set to 1) and the Secondary Channel Offset field is set to a value of SCA or SCB. **3A.6 40-MHz-capable (FC) high-throughput (HT) access point (AP):** An HT AP that included a value of 1 in the Supported Channel Width Set subfield (indicating its capability to operate on a 40 MHz channel) of its most recent transmission of a frame containing an HT Capabilities element. **3A.7 40-MHz-capable (FC) high-throughput (HT) access point (AP) 2G4:** An HT AP 2G4 that is also an FC HT AP. **3A.8 40-MHz-capable (FC) high-throughput (HT) access point (AP) 5G:** An HT AP 5G that is also an FC HT AP. **3A.9 40-MHz-capable (FC) high-throughput (HT) station (STA):** An HT STA that included a value of 1 in the Supported Channel Width Set subfield (indicating its capability to operate on a 40 MHz channel) of its most recent transmission of a frame containing an HT Capabilities element. **3A.10 40-MHz-capable (FC) high-throughput (HT) station (STA) 2G4:** An HT STA 2G4 that is also an FC HT STA. **3A.11 40-MHz-capable (FC) high-throughput (HT) station (STA) 5G:** An HT STA 5G that is also an FC HT STA. **3A.12 40 MHz high throughput (HT):** A Clause 20 transmission using FORMAT=HT_MF or HT_GF and CH_BANDWIDTH=HT_CBW40. Source: IEEE Standard 802.11n-2009 at 3-4.

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>
20. High Throughput (HT) PHY specification

20.1 Introduction

20.1.1 Introduction to the HT PHY

Clause 20 specifies the PHY entity for a high throughput (HT) orthogonal frequency division multiplexing (OFDM) system.

In addition to the requirements found in Clause 20, an HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows:
— In Clause 17 when the HT STA is operating in a 20 MHz channel width in the 5 GHz band
— In Clause 18 and Clause 19 when the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band

The HT PHY is based on the OFDM PHY defined in Clause 17, with extensibility up to four spatial streams, operating in 20 MHz bandwidth. Additionally, transmission using one to four spatial streams is defined for operation in 40 MHz bandwidth. These features are capable of supporting data rates up to 600 Mb/s (four spatial streams, 40 MHz bandwidth).

Source: IEEE Standard 802.11n-2009 at 247.
</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

	40MHZ OFDM 802.11N
	• 802.11n also introduced a 40 MHz channel, which combined two 20 MHz channels
	• The 40 MHz channel consists of 128 subcarriers:
	  • 128 subcarriers:
	    • 108 transmit data subcarriers
	    • 6 as pilot carriers
	    • 14 unused
	• When two 20 MHz HT channels are bonded together, some of the formerly unused subcarriers at the bottom of the higher channel and at the top end of the lower channel are able to be used to transmit data.
	• That is why the number of subcarriers is slightly more than two times the 56 subcarriers in a 20 MHz channel.
	• Each bonded channel consists of a primary and secondary 20 MHz channel.
	• The channels must be adjacent. A positive or negative offset indicates whether the secondary channel is the channel above or the channel below the primary channel. This is pictured in Figure 19.4.
	Source: https://dot11ap.wordpress.com/ht-channel-width-operation/.
	On information and belief, IEEE 802.11ac infringes for the same reasons as 802.11n. *See supra*. *See also*:

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>

3.2 Definitions specific to IEEE 802.11

Change the following definitions in 3.2:

40 MHz mask physical layer (PHY) ~~convergence procedure (PLCP)~~ protocol data unit (PPDU): One of the following PPDUs:
1) ~~a~~A 40 MHz high-throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted using the 40 MHz transmit spectral mask defined in Clause 20.~~;~~
2) ~~a~~A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to NON_HT_CBW40) transmitted by a non-very-high-throughput (non-VHT) STA using the 40 MHz transmit spectral mask defined in Clause 20.~~; or~~
3) A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted by a very high throughput (VHT) STA using the 40 MHz transmit spectral mask defined in Clause 22.
4) ~~a Clause 20~~ A 20 MHz HT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to either CH_OFF_20U or CH_OFF_20L transmitted using the 40 MHz transmit spectral mask defined in Clause 20.
5) A 20 MHz VHT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 40 MHz transmit spectral mask defined in Clause 22.
6) A 40 MHz VHT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW40 transmitted using the 40 MHz transmit spectral mask defined in Clause 22.
7) A 40 MHz HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted by a VHT STA using the 40 MHz transmit spectral mask defined in Clause 22.
8) A 20 MHz non-HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted using the 40 MHz transmit spectral mask defined in Clause 20.
9) A 20 MHz non-HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted by a VHT STA using the 40 MHz transmit spectral mask defined in Clause 22.

~~The PPDU is transmitted using a 40 MHz transmit spectral mask defined in Clause 20 (High Throughput (HT) PHY specification).~~

40 MHz physical layer (PHY) ~~convergence procedure (PLCP)~~ protocol data unit (PPDU): A 40 MHz high-throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40), or a 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to NON_HT_CBW40 or TXVECTOR parameter CH_BANDWIDTH equal to CBW40) ~~as defined in Clause 20~~, or a 40 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40).

Source: IEEE Standard 802.11ac-2013 at 2-3.

</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20. High Throughput (HT) PHY specification **20.1 Introduction** **20.1.1 Introduction to the HT PHY** ***Change the sixth paragraph of 20.1.1 as follows:*** An HT ~~non-AP~~ STA shall support all equal modulation (EQM) rates for one spatial stream (MCSs 0 to 7) using 20 MHz channel width. An HT AP that is not a VHT AP shall support all EQM rates for ~~one and~~ two spatial streams (MCSs ~~0~~ 8 to 15) using 20 MHz channel width. **20.3 HT PLCP sublayer** The HT PHY is based on the OFDM PHY defined in Clause 17, with extensibility up to four spatial streams, operating in 20 MHz bandwidth. Additionally, transmission using one to four spatial streams is defined for operation in 40 MHz bandwidth. These features are capable of supporting data rates up to 600 Mb/s (four spatial streams, 40 MHz bandwidth). Source: IEEE Standard 802.11ac-2013 at 213 (referring to 20.1.1 from the previous IEEE 802.11 draft which was IEEE 802.11-2012):

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20. High Throughput (HT) PHY specification **20.1 Introduction** **20.1.1 Introduction to the HT PHY** Clause 20 specifies the PHY entity for a high throughput (HT) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements found in Clause 20, an HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows: — In Clause 18 when the HT STA is operating in a 20 MHz channel width in the 5 GHz band — In Clause 17 and Clause 19 when the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band The HT PHY is based on the OFDM PHY defined in Clause 18, with extensibility up to four spatial streams, operating in 20 MHz bandwidth. Additionally, transmission using one to four spatial streams is defined for operation in 40 MHz bandwidth. These features are capable of supporting data rates up to 600 Mb/s (four spatial streams, 40 MHz bandwidth). Source: IEEE Standard 802.11-2012 at 1669.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	4.3.10a Very high throughput (VHT) STA This subclause summarizes the normative requirements for an IEEE 802.11 VHT STA stated elsewhere in this standard. The IEEE 802.11 VHT STA operates in frequency bands below 6 GHz excluding the 2.4 GHz band. A VHT STA is an HT STA that, in addition to features supported as an HT STA, supports VHT features identified in Clause 8, Clause 9, Clause 10, Clause 13, Clause 18, and Clause 22. The main PHY features in a VHT STA that are not present in an HT STA are the following: — Mandatory support for 40 MHz and 80 MHz channel widths — Mandatory support for VHT single-user (SU) PPDUs — Optional support for 160 MHz and 80+80 MHz channel widths — Optional support for VHT sounding protocol to support beamforming — Optional support for VHT multi-user (MU) PPDUs — Optional support for VHT-MCSs 8 and 9 Source: IEEE Standard 802.11ac-2013 at 10.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Table 22-38—VHT-MCSs for mandatory 40 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	108	54	1	13.5	15.0
1	QPSK	1/2	2	108	6	216	108	1	27.0	30.0
2	QPSK	3/4	2	108	6	216	162	1	40.5	45.0
3	16-QAM	1/2	4	108	6	432	216	1	54.0	60.0
4	16-QAM	3/4	4	108	6	432	324	1	81.0	90.0
5	64-QAM	2/3	6	108	6	648	432	1	108.0	120.0
6	64-QAM	3/4	6	108	6	648	486	1	121.5	135.0
7	64-QAM	5/6	6	108	6	648	540	1	135.0	150.0
8	256-QAM	3/4	8	108	6	864	648	1	162.0	180.0
9	256-QAM	5/6	8	108	6	864	720	1	180.0	200.0

See also IEEE Standard 802.11ac-2009 at 328, where a 40 MHz Modulation and Coding Scheme (MCS) is mandatory.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)

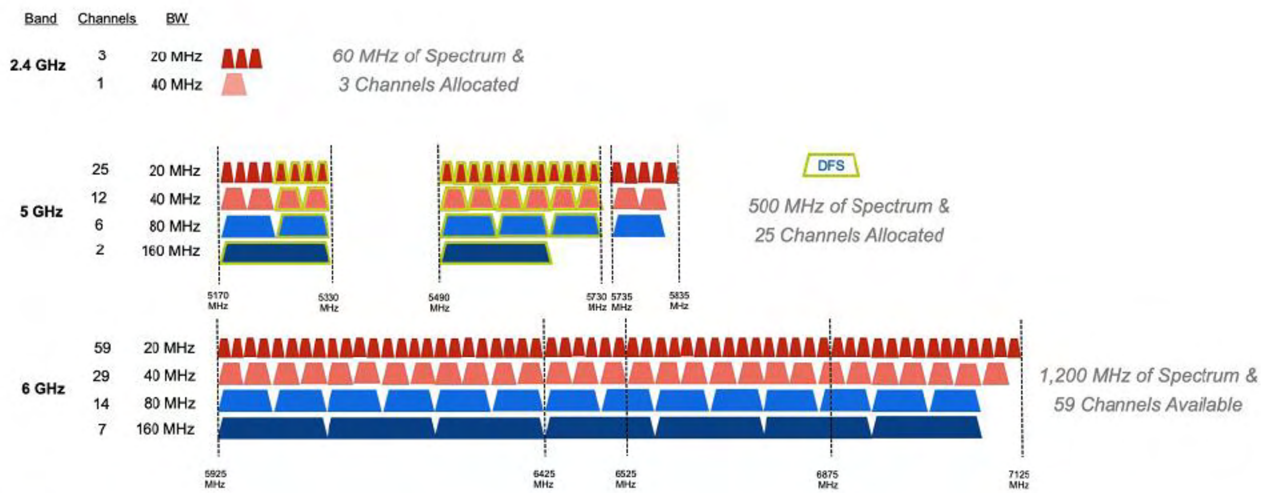
Claim 1	Example Viasat Systems and Services
	Table 22-46—VHT-MCSs for mandatory 80 MHz, N_{SS} = 1 (table below) *See also* IEEE Standard 802.11ac-2013 at 332, where an 80 MHz Modulation and Coding Scheme (MCS) is mandatory.
[1.a] selecting at least a first channel and a second channel, wherein the first channel and the second channel are adjacent without any other channels therebetween, wherein the first channel and the second	On information and belief, the Viasat Systems and Services practice selecting at least a first channel and a second channel, wherein the first channel and the second channel are adjacent without any other channels therebetween, wherein the first channel and the second channel each have a plurality of data subcarriers, wherein the data subcarriers of the first channel and the data subcarriers of the second channel are separated by a frequency gap corresponding to one or more guard bands between the first and second channels. On information and belief, an IEEE 802.11n-2009 HT STA selects a Primary Channel and a Secondary Channel as indicated via the HT Operation element.

Table 22-46—VHT-MCSs for mandatory 80 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	234	8	234	117	1	29.3	32.5
1	QPSK	1/2	2	234	8	468	234	1	58.5	65.0
2	QPSK	3/4	2	234	8	468	351	1	87.8	97.5
3	16-QAM	1/2	4	234	8	936	468	1	117.0	130.0
4	16-QAM	3/4	4	234	8	936	702	1	175.5	195.0
5	64-QAM	2/3	6	234	8	1404	936	1	234.0	260.0
6	64-QAM	3/4	6	234	8	1404	1053	1	263.3	292.5
7	64-QAM	5/6	6	234	8	1404	1170	1	292.5	325.0
8	256-QAM	3/4	8	234	8	1872	1404	1	351.0	390.0
9	256-QAM	5/6	8	234	8	1872	1560	1	390.0	433.3

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td>channel each have a plurality of data subcarriers, wherein the data subcarriers of the first channel and the data subcarriers of the second channel are separated by a frequency gap corresponding to one or more guard bands between the first and second channels;</td><td>Between the 2.4 GHz and 5 GHz spectrum available for Wi-Fi, there are 13 such 40 MHz channels that can occur:



Source: https://www.everythingrf.com/community/what-frequency-band-does-wi-fi-6e-use.

In each of these 13 cases, the two previous 20-MHz channels that each had a 1 MHz guard band between these channels, now becomes one 40-MHz channel that can make use of those two 1 MHz guard bands between the two formerly 20-MHz channels:</td></tr>
</table>

[redacted]

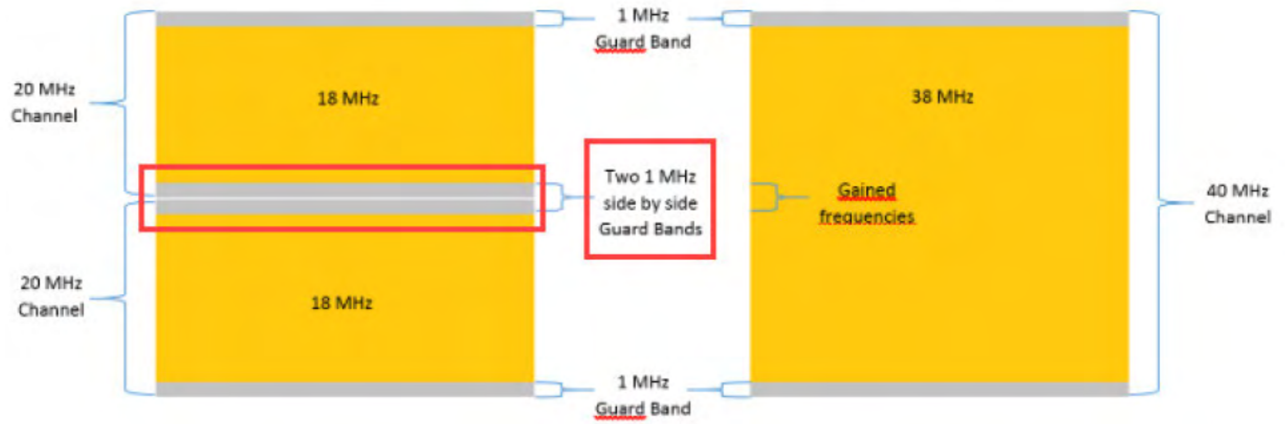
<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>

Figure 9: Gained frequencies from previous Gard Bands when using Channel Bonding

In fact, channel bounding more than doubles the throughput. One 20 MHz channel is composed of two 1 MHz channels, one at the beginning of the channel and one at the end, called Guard Bands. The 18 MHz left are used for data transfers. When using Channel Bonding, the two Guard Bands between two 20 MHz channels can now be used carry information.

Source:
https://www.gta.ufrj.br/ensino/eel879/trabalhos_vf_2014_2/remi/Physical%20Layer%20Improvements.html.</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

	40MHZ OFDM 802.11N
	
	• 802.11n also introduced a 40 MHz channel, which combined two 20 MHz channels
	• The 40 MHz channel consists of 128 subcarriers:
	  • 128 subcarriers:
	    • 108 transmit data subcarriers
	    • 6 as pilot carriers
	    • 14 unused
	
	• When two 20 MHz HT channels are bonded together, some of the formerly unused subcarriers at the bottom of the higher channel and at the top end of the lower channel are able to be used to transmit data.
	• That is why the number of subcarriers is slightly more than two times the 56 subcarriers in a 20 MHz channel.
	• Each bonded channel consists of a primary and secondary 20 MHz channel.
	• The channels must be adjacent. A positive or negative offset indicates whether the secondary channel is the channel above or the channel below the primary channel. This is pictured in Figure 19.4.
	
	Source: https://dot11ap.wordpress.com/ht-channel-width-operation/.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Radio Enhancements

802.11n uses both 20-MHz and 40-MHz channels. Like the proprietary products, the 40-MHz channels in 802.11n are two adjacent 20-MHz channels, bonded together. When using the 40-MHz bonded channel,802.11n takes advantage of the fact that each 20-MHz channel has a small amount of the channel that is reserved at the top and bottom, to reduce interference in those adjacent channels. When using 40-MHz channels, the top of the lower channel and the bottom of the upper channel don't have to be reserved to avoid interference. These small parts of the channel can now be used to carry information. By using the two 20-MHz channels more efficiently in this way, 802.11n achieves slightly more than doubling the data rate when moving from 20-MHz to 40-MHz channels.

Source: https://vocal.com/networking/ieee-802-11n/.

Channel Bonding

Channel bonding is used in 802.11n to bind two 20 MHz channels, to make one 40 MHz channel. Doubling the frequency space doubles the bandwidth, and doubling the bandwidth doubles the throughput. We can make an analogy with a highway. Moving from a two lines highway to a four lines highway doubles the traffic capacity. Same result applies in network. While 802.11a and g used 20 MHz channels, 802.11n uses 40MHz channels, thanks to Channel Bonding (see the following figure).

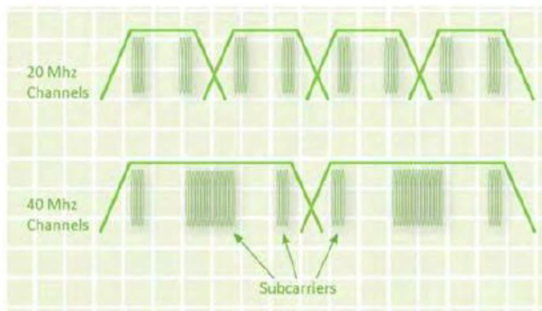


Figure 8: Channel Bonding

Source: https://www.gta.ufrj.br/ensino/eel879/trabalhos_vf_2014_2/remi/Physical%20Layer%20Improvements.html.

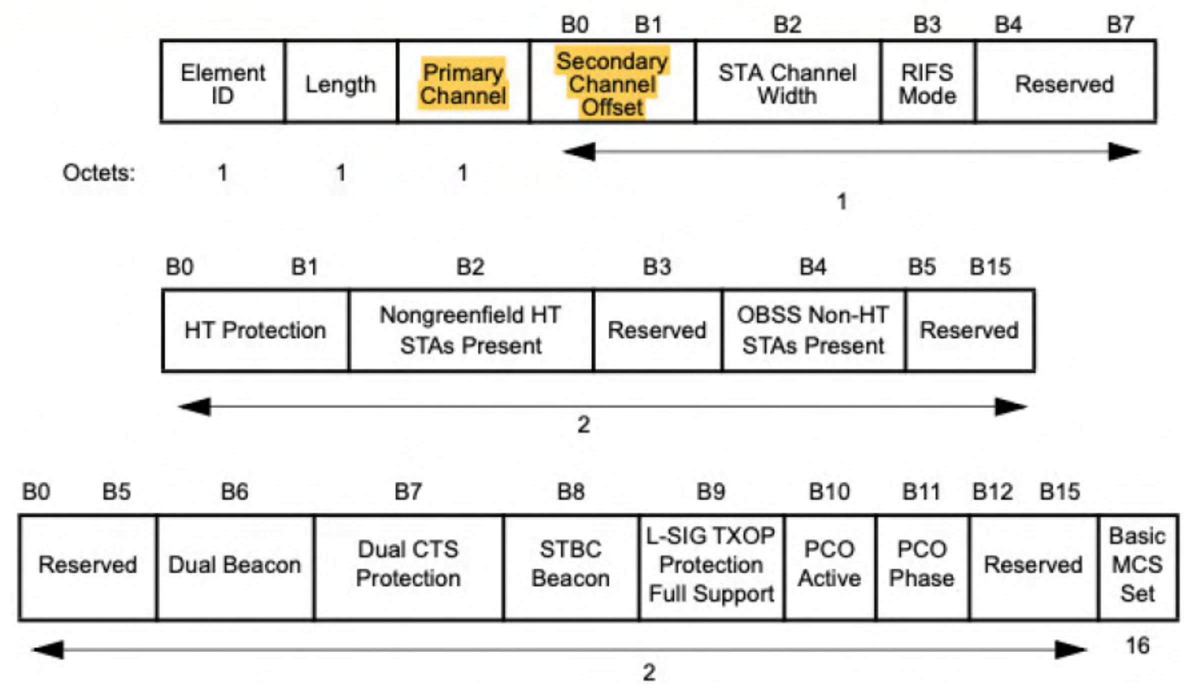
This is also described in IEEE 802.11n-2009:

3. Definitions

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	3.242 primary channel: The common channel of operation for all stations (STAs) that are members of the basic service set (BSS). **3A.61 secondary channel:** A 20 MHz channel associated with a primary channel used by high-throughput (HT) stations (STAs) for the purpose of creating a 40 MHz channel. Source: IEEE Standard 802.11n-2009 at 2, 7.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	7.3.2.57 HT Operation element The operation of HT STAs in the BSS is controlled by the HT Operation element. The structure of this element is defined in Figure 7-95o24.  **Figure 7-95o24—HT Operation element format** Source: IEEE Standard 802.11n-2009 at 76.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	The fields of the HT Operation element are defined in Table 7-43p. The "Reserved in IBSS?" column indicates whether each field is reserved (Y) or not reserved (N) when this element is present in a frame transmitted within an IBSS. **Table 7-43p—HT Operation element** (table below) Source: IEEE Standard 802.11n-2009 at 77.

Table 7-43p—HT Operation element

Field	Definition	Encoding	Reserved in IBSS ?
Primary Channel	Indicates the channel number of the primary channel. See 11.14.2.	Channel number of the primary channel	N
Secondary Channel Offset	Indicates the offset of the secondary channel relative to the primary channel.	Set to 1 (SCA) if the secondary channel is above the primary channel Set to 3 (SCB) if the secondary channel is below the primary channel Set to 0 (SCN) if no secondary channel is present The value 2 is reserved	N

Source: IEEE Standard 802.11n-2009 at 77.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Table 20-5—Timing-related constants

Parameter	TXVECTOR CH_BANDWIDTH			
	NON_HT_CBW20	HT_CBW_20	HT_CBW40 or NON_HT_CBW40	
			HT format	MCS 32 and non-HT duplicate
N_{SD}: Number of complex data numbers	48	52	108	48
N_{SP}: Number of pilot values	4	4	6	4
N_{ST}: Total number of subcarriers See NOTE 1	52	56	114	104

Source: IEEE Standard 802.11n-2009 at Table 20-5.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20.3.11.10.3 Transmission in 40 MHz HT format For 40 MHz HT transmissions, the signal from transmit chain i_{TX} shall be as shown in Equation (20-59). $$r^{i_{TX}}_{HT-DATA}(t) = \frac{1}{\sqrt{N_{STS} \cdot N^{Tone}_{HT-DATA}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} ([Q_k]_{i_{TX}, i_{STS}} (\tilde{D}_{k, i_{STS}, n} + p_{n+z} P^k_{(i_{STS}, n)}) \Upsilon_k \cdot \exp(j2\pi k \Delta_F (t - nT_{SYM} - T_{GI} - T^{i_{STS}}_{CS}))) \quad (20\text{-}59)$$ Copyright © 2009 IEEE. All rights reserved. 301

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>

where

z is 3 in an HT-mixed format packet and 2 in an HT-greenfield format packet

p_n is defined in 17.3.5.9

$$\tilde{D}_{k,\, i_{STS},\, n} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ \tilde{d}_{M^r(k),\, i_{STS},\, n}, \text{ otherwise} \end{cases}$$

$$M^r(k) = \begin{cases} k + 58, -58 \le k \le -54 \\ k + 57, -52 \le k \le -26 \\ k + 56, -24 \le k \le -12 \\ k + 55, -10 \le k \le -2 \\ k + 52, 2 \le k \le 10 \\ k + 51, 12 \le k \le 24 \\ k + 50, 26 \le k \le 52 \\ k + 49, 54 \le k \le 58 \end{cases}$$

$P^k_{(i_{STS},\, n)}$ is defined in Equation (20-55)

NOTE—The 90º rotation that is applied to the upper part of the 40 MHz channel is applied in the same way to the HT-STF, HT-LTF, and HT-SIG. The rotation applies to both pilots and the data in the upper part of the 40 MHz channel.

Source: IEEE Standard 802.11n-2009 at 301-302.

</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Grouping is a method that reduces the size of the CSI Report field by reporting a single value for each group of Ng adjacent subcarriers. With grouping, the size of the CSI Report field is $Nr \times 8 + Ns \times (3 + 2 \times Nb \times Nc \times Nr)$ bits, where the number of subcarriers sent, Ns, is a function of Ng and whether matrices for 40 MHz or 20 MHz are sent. The value of Ns and the specific carriers for which matrices are sent are shown in Table 7-25f. If the size of the CSI Report field is not an integral multiple of 8 bits, up to 7 zeros are appended to the end of the report to make its size an integral multiple of 8 bits.

Table 7-25f—Number of matrices and carrier grouping

BW	Grouping *Ng*	*Ns*	Carriers for which matrices are sent
20 MHz	1	56	All data and pilot carriers: –28, –27,…–2, –1, 1, 2,…27, 28
	2	30	–28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–2,–1, 1,3,5,7,9,11,13,15,17,19,21,23,25,27,28
	4	16	–28,–24,–20,–16,–12,–8,–4,–1,1,5,9,13,17,21,25,28
40 MHz	1	114	All data and pilot carriers: –58, –57, …, –3, –2, 2, 3,…, 57, 58
	2	58	–58,–56,–54,–52,–50,–48,–46,–44,–42,–40,–38,–36,–34,–32,–30, –28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–2, 2,4,6,8,10,12,14,16,18,20,22,24,26,28, 30,32,34,36,38,40,42,44,46,48,50,52,54,56,58
	4	30	–58,–54,–50,–46,–42,–38,–34,–30,–26,–22,–18,–14,–10,–6, –2, 2,6,10,14,18,22,26,30,34,38,42,46,50,54,58

Source: IEEE Standard 802.11n-2009 at 50.

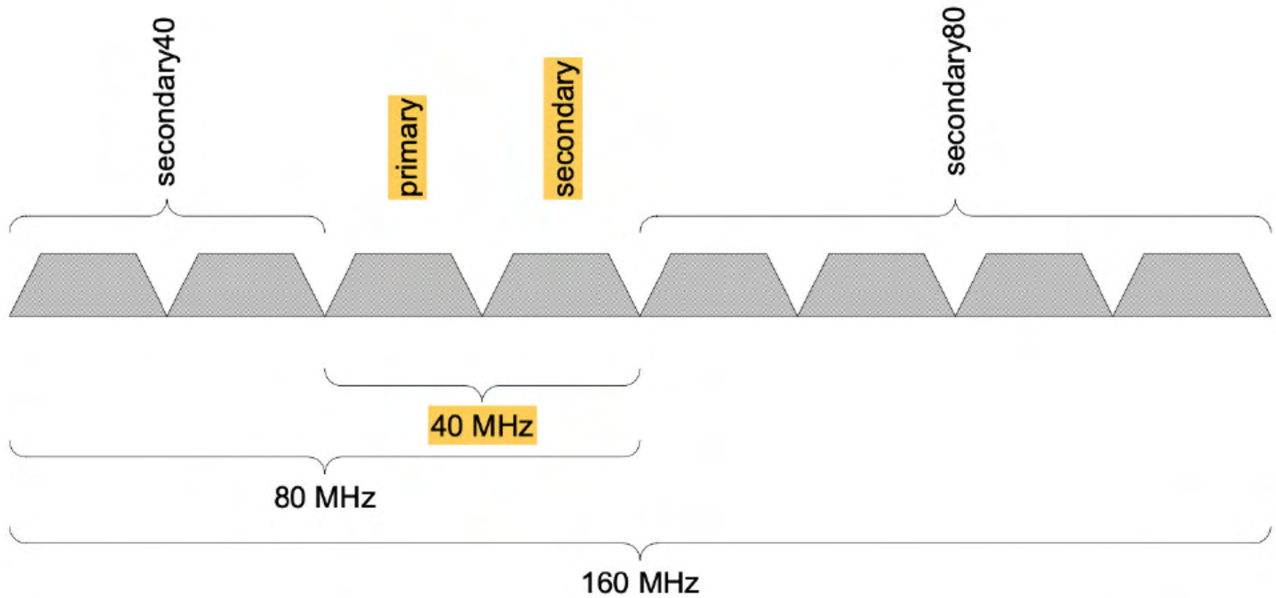
On information and belief, IEEE 802.11ac infringes for the same reasons as IEEE 802.11n. *See supra*. *See also*:

3.2 Definitions specific to IEEE 802.11

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	primary 20 MHz channel: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel that is used to transmit 20 MHz physical layer (PHY) protocol data units (PPDUs). In a VHT BSS, the primary 20 MHz channel is also the primary channel. **primary 40 MHz channel:** In an 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 40 MHz channel that is used to transmit 40 MHz physical layer (PHY) protocol data units (PPDUs). **primary 80 MHz channel:** In a 160 MHz or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 80 MHz channel that is used to transmit 80 MHz physical layer (PHY) protocol data units (PPDUs). **primary access category (AC):** The access category (AC) associated with the enhanced distributed channel access function (EDCAF) that gains channel access. **secondary 20 MHz channel**: In a 40 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel adjacent to the primary 20 MHz channel that together form the 40 MHz channel of the 40 MHz VHT BSS. In an 80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 80 MHz VHT BSS. In a 160 MHz or 80+80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 160 MHz or 80+80 MHz VHT BSS. In a VHT BSS, the secondary 20 MHz channel is also the secondary channel. **secondary channel**: A 20 MHz channel associated with a primary channel used by high-throughput (HT) stations (STAs) for the purpose of creating a 40 MHz channel or used by very high throughput (VHT) stations (STAs) for the purpose of creating the primary 40 MHz channel. **non-primary channel**: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), any 20 MHz channel other than the primary 20 MHz channel. Source: IEEE Standard 802.11ac-2013 at 2, 4, 7.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	 **Figure 7-1—The channel-list parameter element for 40 MHz, 80 MHz, and 160 MHz channel width** Source: IEEE Standard 802.11ac-2013 at 31.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	4.3.10a Very high throughput (VHT) STA This subclause summarizes the normative requirements for an IEEE 802.11 VHT STA stated elsewhere in this standard. The IEEE 802.11 VHT STA operates in frequency bands below 6 GHz excluding the 2.4 GHz band. A VHT STA is an HT STA that, in addition to features supported as an HT STA, supports VHT features identified in Clause 8, Clause 9, Clause 10, Clause 13, Clause 18, and Clause 22. The main PHY features in a VHT STA that are not present in an HT STA are the following: — Mandatory support for 40 MHz and 80 MHz channel widths — Mandatory support for VHT single-user (SU) PPDUs — Optional support for 160 MHz and 80+80 MHz channel widths — Optional support for VHT sounding protocol to support beamforming — Optional support for VHT multi-user (MU) PPDUs — Optional support for VHT-MCSs 8 and 9 Source: IEEE Standard 802.11ac-2013 at 10.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.5 Parameters for VHT-MCSs The rate-dependent parameters for 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz $N_{SS} = 1, \ldots, 8$ are given in Table 22-30 through Table 22-61. Support for 400 ns GI is optional in all cases. Support for VHT-MCS 8 and 9 (when valid) is optional in all cases. A VHT STA shall support single spatial stream VHT-MCSs within the range VHT-MCS 0 to VHT-MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported VHT-MCS and NSS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported VHT-MCS and NSS Set field may result in a reduced VHT-MCS range (cut-off) for $N_{SS} = 2, \ldots, 8$. Support for 20 MHz, 40 MHz, and 80 MHz with $N_{SS} = 1$ is mandatory. Support for 20 MHz, 40 MHz, and 80 MHz with $N_{SS} = 2, \ldots, 8$ is optional. Support for 160 MHz and 80+80 MHz with $N_{SS} = 1, \ldots, 8$ is optional. N_{ES} values were chosen to yield an integer number of punctured blocks for each BCC encoder per OFDM symbol. Table 22-30 to Table 22-33, Table 22-38 to Table 22-41, Table 22-46 to Table 22-49, and Table 22-54 to Table 22-57 define VHT-MCSs not only for SU transmission but also for user u of MU transmission. In the case of VHT-MCSs for MU transmission, the parameters, N_{SS}, R, N_{BPSCS}, N_{CBPS}, N_{DBPS}, and N_{ES} are replaced with $N_{SS,u}$, R_u, $N_{BPSCS,u}$, $N_{CBPS,u}$, $N_{DBPS,u}$, and $N_{ES,u}$, respectively. Source: IEEE Standard 802.11ac-2013 at 323.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Table 22-38—VHT-MCSs for mandatory 40 MHz, N_{SS} = 1 (see table below) Source: IEEE Standard 802.11ac-2013 at 328.

VHT-MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	108	54	1	13.5	15.0
1	QPSK	1/2	2	108	6	216	108	1	27.0	30.0
2	QPSK	3/4	2	108	6	216	162	1	40.5	45.0
3	16-QAM	1/2	4	108	6	432	216	1	54.0	60.0
4	16-QAM	3/4	4	108	6	432	324	1	81.0	90.0
5	64-QAM	2/3	6	108	6	648	432	1	108.0	120.0
6	64-QAM	3/4	6	108	6	648	486	1	121.5	135.0
7	64-QAM	5/6	6	108	6	648	540	1	135.0	150.0
8	256-QAM	3/4	8	108	6	864	648	1	162.0	180.0
9	256-QAM	5/6	8	108	6	864	720	1	180.0	200.0

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	(see Table 22-5 below)

Table 22-5—Timing-related constants

Parameter	CBW20	CBW40	CBW80	CBW80+80	CBW160	Description
N_{SD}	52	108	234	234	468	Number of complex data numbers per frequency segment
N_{SP}	4	6	8	8	16	Number of pilot values per frequency segment
N_{ST}	56	114	242	242	484	Total number of subcarriers per frequency segment. See NOTE.
N_{SR}	28	58	122	122	250	Highest data subcarrier index per frequency segment
N_{Seg}	1	1	1	2	1	Number of frequency segments
Δ_F	312.5 kHz					Subcarrier frequency spacing
T_{DFT}	3.2 µs					IDFT/DFT period

Source: IEEE Standard 802.11ac-2013 at Table 20-5.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.3.7.3 Channel frequencies Let $f_{c,\ \text{idx0}} = \text{dot11CurrentChannelCenterFrequencyIndex0}$ (22-1) $f_{c,\ \text{idx1}} = \text{dot11CurrentChannelCenterFrequencyIndex1}$ (22-2) $f_{\text{P20, idx}} = \text{dot11CurrentPrimaryChannel}$ (22-3) $f_{\text{CH, start}} = \text{dot11ChannelStartingFactor} \times 500\ \text{kHz}$ (22-4) where dot11CurrentChannelCenterFrequencyIndex0, dot11CurrentChannelCenterFrequencyIndex1, and dot11CurrentPrimaryChannel are defined in Table 22-22. When dot11CurrentChannelWidth (see Table 22-22) is 20 MHz, $f_{\text{P20, idx}} = f_{c,\ \text{idx0}}$. For dot11CurrentChannelWidth greater than 20 MHz, $f_{\text{P20, idx}}$ and $f_{c,\ \text{idx0}}$ shall have the relationship specified in Equation (22-5). $f_{\text{P20, idx}} = f_{c,\ \text{idx0}} - 4 \cdot \left(\frac{N_{\text{20MHz}}}{2} - n_{\text{P20}}\right) + 2$ (22-5) where $N_{\text{20MHz}} = \begin{cases} 2, \text{ if dot11CurrentChannelWidth indicates 40 MHz} \\ 4, \text{ if dot11CurrentChannelWidth indicates 80 MHz and 80+80 MHz} \\ 8, \text{ if dot11CurrentChannelWidth indicates 160 MHz} \end{cases}$ Source: IEEE Standard 802.11ac-2013 at 248.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.3.7.4 Transmitted signal The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (22-11). $$r_{RF}^{(i_{Seg},\, i_{TX})}(t) = \mathrm{Re}\left\{ \frac{1}{\sqrt{N_{Seg}}} r_{\mathrm{PPDU}}^{(i_{Seg},\, i_{TX})}(t) \exp\left(j2\pi f_c^{(i_{Seg})} t\right) \right\}, \quad (22\text{-}11)$$ $$i_{Seg} = 0, \ldots, N_{Seg} - 1; \quad i_{TX} = 1, \ldots, N_{TX}$$ where $\mathrm{Re}\{.\}$ represents the real part of a complex variable; N_{Seg} represents the number of frequency segments in the transmit signal, as defined in Table 22-5; $r_{\mathrm{PPDU}}^{(i_{Seg},\, i_{TX})}(t)$ represents the complex baseband signal of frequency segment i_{Seg} in transmit chain i_{TX}; $f_c^{(i_{Seg})}$ represents the center frequency of the portion of the PPDU transmitted in frequency segment i_{Seg}. Table 22-7 shows $f_c^{(i_{Seg})}$ as a function of the channel starting frequency and dot11CurrentChannelWidth (see Table 22-22) where $f_{\mathrm{P20,\,idx}}$, $f_{\mathrm{P40,\,idx}}$, and $f_{\mathrm{P80,\,idx}}$ are given in Equation (22-4), Equation (22-5), Equation (22-7), and Equation (22-9), respectively. NOTE—Transmitted signals may have different impairments such as phase offset or phase noise between the two frequency segments, which is not shown in Equation (22-11) for simplicity. See 22.3.18.3. Source: IEEE Standard 802.11ac-2013 at 249.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Table 8-53g—Subcarriers for which a Compressed Beamforming Feedback Matrix subfield is sent back

Channel Width	*Ng*	*Ns*	Subcarriers for which Compressed Feedback Beamforming Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1)
20 MHz	1	52	–28, –27, –26, –25, –24, –23, –22, –20, –19, –18, –17, –16, –15, –14, –13, –12, –11, –10, –9, –8, –6, –5, –4, –3, –2, –1, 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28 NOTE—Pilot subcarriers (±21, ±7) and DC subcarrier (0) are skipped
	2	30	–28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28
	4	16	–28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28
40 MHz	1	108	–58, –57, –56, –55, –54, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58 NOTE—Pilot subcarriers (±53, ±25, ±11) and DC subcarriers (0, ±1) are skipped.
	2	58	–58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, -22, –20, –18, –16, –14, –12, –10, –8, –6, –4,–2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58
	4	30	–58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6,–2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58

Source: IEEE Standard 802.11ac-2013 at 59.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Table 8-53j—Number of subcarriers and subcarrier mapping

Channel Width	*Ng*	*Ns′*	Subcarriers for which the Delta SNR subfield is sent: *sscidx*(0), *sscidx*(1), … *sscidx*(*Ns′*–1)
20 MHz	1	30	–28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28
	2	16	–28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28
	4	10	–28, –20, –12, –4, –1, 1, 4, 12, 20, 28
40 MHz	1	58	–58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4,–2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58
	2	30	–58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6,–2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58
	4	16	–58, –50, –42, –34, –26, –18, –10, –2, 2, 10, 18, 26, 34, 42, 50, 58

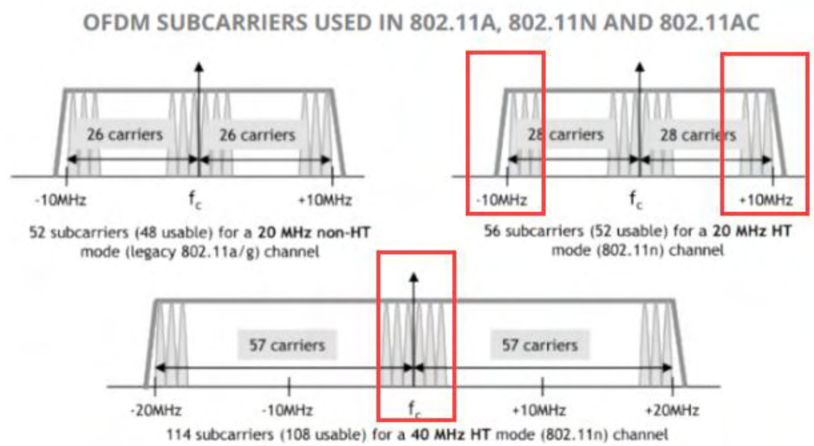
Source: IEEE Standard 802.11ac-2013 at 66.

[redacted]

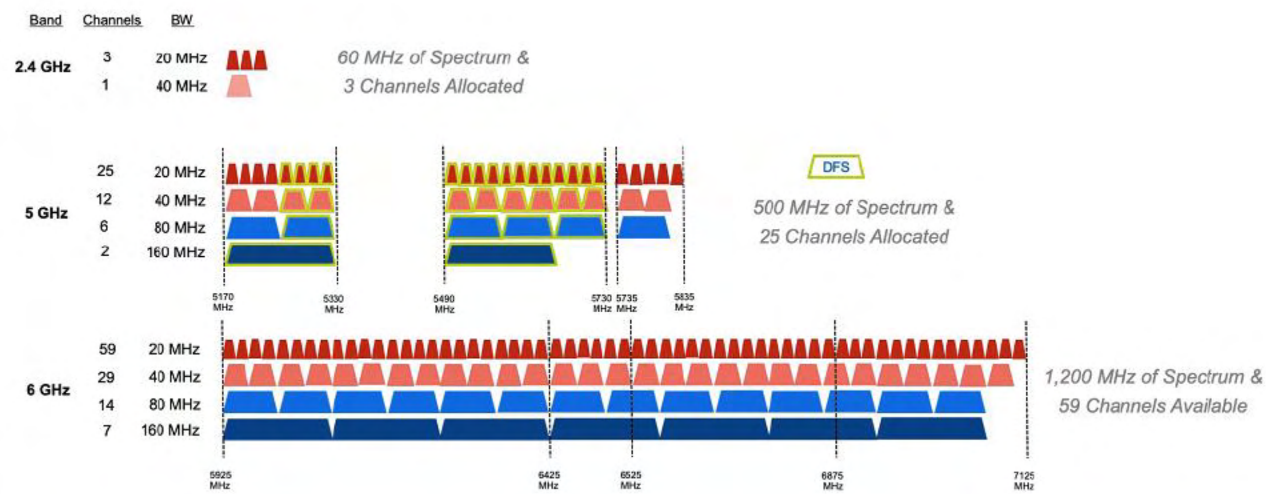
<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>
Table 10-19—VHT BSS operating channel width
<table>
<tr><th>HT Operation element STA Channel Width field</th><th>VHT Operation element Channel Width field</th><th>BSS operating channel width</th></tr>
<tr><td>0</td><td>0</td><td>20 MHz</td></tr>
<tr><td>1</td><td>0</td><td>40 MHz</td></tr>
<tr><td>1</td><td>1</td><td>80 MHz</td></tr>
<tr><td>1</td><td>2</td><td>160 MHz</td></tr>
<tr><td>1</td><td>3</td><td>80+80 MHz</td></tr>
</table>
Source: IEEE Standard 802.11ac-2013 at 186.
</td></tr>
<tr><td>[1.b] partially filling the frequency gap between the first channel and the second channel by adding one or more data subcarriers into the frequency gap such that the one or more guard bands are at least partially filled with at least some of the one or more data subcarriers using full spectral synthesis capability of a fast fourier transform or</td><td>On information and belief, the Viasat Systems and Services practice partially filling the frequency gap between the first channel and the second channel by adding one or more data subcarriers into the frequency gap such that the one or more guard bands are at least partially filled with at least some of the one or more data subcarriers using full spectral synthesis capability of a fast fourier transform or an inverse fast fourier transform.

On information and belief, a 2 MHz frequency gap is present between the outer subcarriers of adjacent 20 MHz channels. In a 40 MHz bonded channel, this gap is partially filled with additional subcarriers.</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
an inverse fast fourier transform;	 Source: https://www.cablefree.net/wirelesstechnology/802-11ac/. Between the 2.4 GHz and 5 GHz spectrum available for Wi-Fi, there are 13 such 40 MHz channels that can occur:

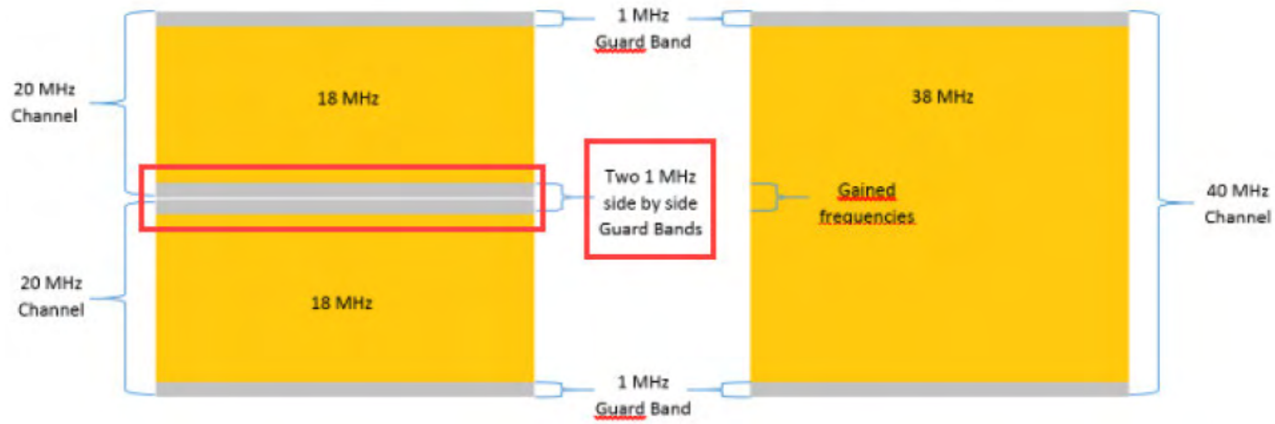
[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>


Source: https://www.everythingrf.com/community/what-frequency-band-does-wi-fi-6e-use.

In each of these 13 cases, the two previous two 20-MHz channels that each had a 1 MHz guard band between these channels, now becomes one 40-MHz channel that can make use of those two 1 MHz guard bands between the two formerly 20-MHz channels:
</td></tr>
</table>

[redacted]

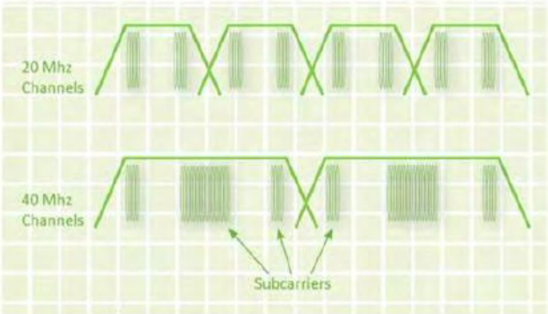
U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	 Figure 9: Gained frequencies from previous Gard Bands when using Channel Bonding In fact, channel bounding more than doubles the throughput. One 20 MHz channel is composed of two 1 MHz channels, one at the beginning of the channel and one at the end, called Guard Bands. The 18 MHz left are used for data transfers. When using Channel Bonding, the two Guard Bands between two 20 MHz channels can now be used carry information. Source: https://www.gta.ufrj.br/ensino/eel879/trabalhos_vf_2014_2/remi/Physical%20Layer%20Improvements.html.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

	40MHZ OFDM 802.11N
	
	• 802.11n also introduced a 40 MHz channel, which combined two 20 MHz channels
	• The 40 MHz channel consists of 128 subcarriers:
	  • 128 subcarriers:
	    • 108 transmit data subcarriers
	    • 6 as pilot carriers
	    • 14 unused
	
	• When two 20 MHz HT channels are bonded together, some of the formerly unused subcarriers at the bottom of the higher channel and at the top end of the lower channel are able to be used to transmit data.
	• That is why the number of subcarriers is slightly more than two times the 56 subcarriers in a 20 MHz channel.
	• Each bonded channel consists of a primary and secondary 20 MHz channel.
	• The channels must be adjacent. A positive or negative offset indicates whether the secondary channel is the channel above or the channel below the primary channel. This is pictured in Figure 19.4.
	
	Source: https://dot11ap.wordpress.com/ht-channel-width-operation/.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Radio Enhancements 802.11n uses both 20-MHz and 40-MHz channels. Like the proprietary products, the 40-MHz channels in 802.11n are two adjacent 20-MHz channels, bonded together. When using the 40-MHz bonded channel,802.11n takes advantage of the fact that each 20-MHz channel has a small amount of the channel that is reserved at the top and bottom, to reduce interference in those adjacent channels. When using 40-MHz channels, the top of the lower channel and the bottom of the upper channel don't have to be reserved to avoid interference. These small parts of the channel can now be used to carry information. By using the two 20-MHz channels more efficiently in this way, 802.11n achieves slightly more than doubling the data rate when moving from 20-MHz to 40-MHz channels. Source: https://vocal.com/networking/ieee-802-11n/. **Channel Bonding** Channel bonding is used in 802.11n to bind two 20 MHz channels, to make one 40 MHz channel. Doubling the frequency space doubles the bandwidth, and doubling the bandwidth doubles the throughput. We can make an analogy with a highway. Moving from a two lines highway to a four lines highway doubles the traffic capacity. Same result applies in network. While 802.11a and g used 20 MHz channels, 802.11n uses 40MHz channels, thanks to Channel Bonding (see the following figure).  Figure 8: Channel Bonding Source: https://www.gta.ufrj.br/ensino/eel879/trabalhos_vf_2014_2/remi/Physical%20Layer%20Improvements.html This is also described in IEEE 802.11n-2009.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Grouping is a method that reduces the size of the CSI Report field by reporting a single value for each group of *Ng* adjacent subcarriers. With grouping, the size of the CSI Report field is $Nr \times 8 + Ns \times (3 + 2 \times Nb \times Nc \times Nr)$ bits, where the number of subcarriers sent, *Ns*, is a function of *Ng* and whether matrices for 40 MHz or 20 MHz are sent. The value of *Ns* and the specific carriers for which matrices are sent are shown in Table 7-25f. If the size of the CSI Report field is not an integral multiple of 8 bits, up to 7 zeros are appended to the end of the report to make its size an integral multiple of 8 bits.

Table 7-25f—Number of matrices and carrier grouping

BW	Grouping *Ng*	*Ns*	Carriers for which matrices are sent
20 MHz	1	56	All data and pilot carriers: –28, –27,…–2, –1, 1, 2,…27, 28
	2	30	–28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–2,–1, 1,3,5,7,9,11,13,15,17,19,21,23,25,27,28
	4	16	–28,–24,–20,–16,–12,–8,–4,–1,1,5,9,13,17,21,25,28
40 MHz	1	114	All data and pilot carriers: –58, –57, …, –3, –2, 2, 3,…, 57, 58
	2	58	–58,–56,–54,–52,–50,–48,–46,–44,–42,–40,–38,–36,–34,–32,–30, –28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–2, 2,4,6,8,10,12,14,16,18,20,22,24,26,28, 30,32,34,36,38,40,42,44,46,48,50,52,54,56,58
	4	30	–58,–54,–50,–46,–42,–38,–34,–30,–26,–22,–18,–14,–10,–6, –2, 2,6,10,14,18,22,26,30,34,38,42,46,50,54,58

Source: IEEE Standard 802.11n-2009 at 50.

On information and belief, a 2 MHz frequency gap is present between the outer subcarriers of adjacent 20 MHz channels. In a 40 MHz bonded channel, this gap (6 sub carriers is partially filled with four additional subcarriers, corresponding to indexes –3,-2, +2 and +3. When two 20 MHz HT channels are bonded together, some of the formerly unused subcarriers at the bottom of the higher channel and at the top end of the lower channel can be used to transmit data, and the number of data subcarriers is slightly more than twice the number of subcarriers in a 40 MHz channel, as shown in the evidence below.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	(see below)

Table 20-5—Timing-related constants

Parameter	TXVECTOR CH_BANDWIDTH			
	NON_HT_CBW20	HT_CBW_20	HT_CBW40 or NON_HT_CBW40	
			HT format	MCS 32 and non-HT duplicate
N_{SD}: Number of complex data numbers	48	52	108	48
N_{SP}: Number of pilot values	4	4	6	4
N_{ST}: Total number of subcarriers See NOTE 1	52	56	114	104

Source: IEEE Standard 802.11n-2009 at Table 20-5.

CH_BANDWIDTH	FORMAT is HT_MF or HT_GF	Indicates whether the packet is transmitted using 40 MHz or 20 MHz channel width. Enumerated type: HT_CBW20 for 20 MHz and 40 MHz upper and 40 MHz lower modes HT_CBW40 for 40 MHz	Y	Y
	FORMAT is NON_HT	Enumerated type: NON_HT_CBW40 for non-HT duplicate format NON_HT_CBW20 for all other non-HT formats	Y	Y

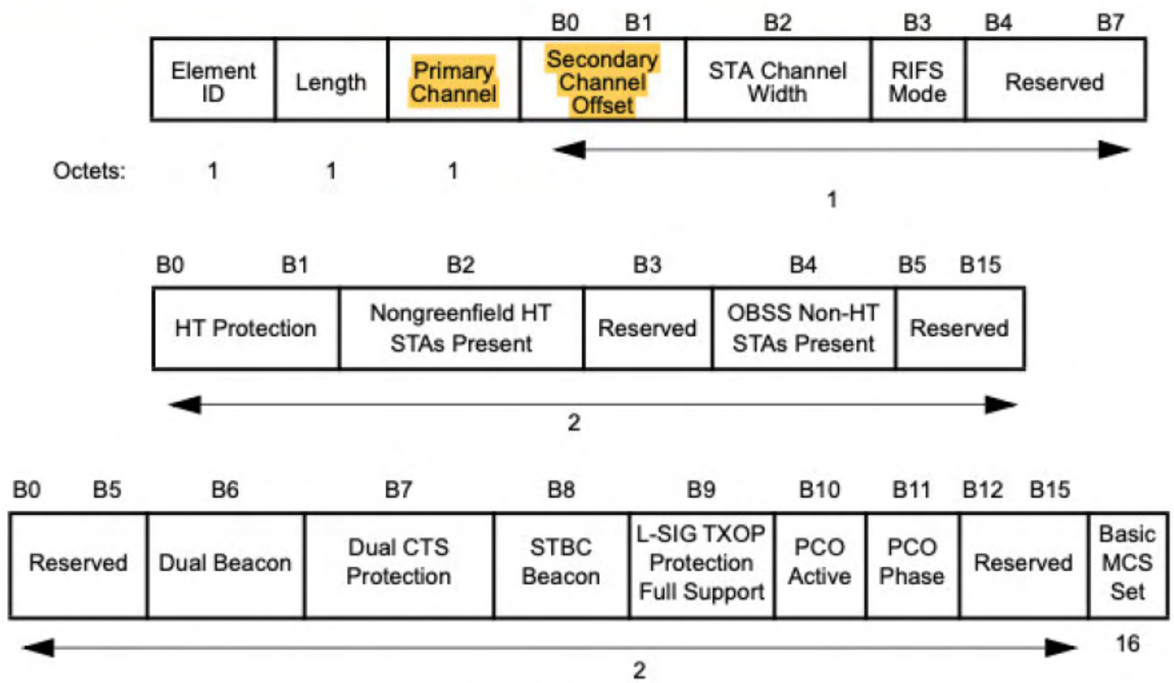
Source: IEEE Standard 802.11n-2009 at 251.

3. Definitions

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	3.242 primary channel: The common channel of operation for all stations (STAs) that are members of the basic service set (BSS). **3A.61 secondary channel:** A 20 MHz channel associated with a primary channel used by high-throughput (HT) stations (STAs) for the purpose of creating a 40 MHz channel. Source: IEEE Standard 802.11n-2009 at 2, 7.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	7.3.2.57 HT Operation element The operation of HT STAs in the BSS is controlled by the HT Operation element. The structure of this element is defined in Figure 7-95o24.  **Figure 7-95o24—HT Operation element format** Source: IEEE Standard 802.11n-2009 at 76.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	The fields of the HT Operation element are defined in Table 7-43p. The "Reserved in IBSS?" column indicates whether each field is reserved (Y) or not reserved (N) when this element is present in a frame transmitted within an IBSS.

Table 7-43p—HT Operation element

Field	Definition	Encoding	Reserved in IBSS ?
Primary Channel	Indicates the channel number of the primary channel. See 11.14.2.	Channel number of the primary channel	N
Secondary Channel Offset	Indicates the offset of the secondary channel relative to the primary channel.	Set to 1 (SCA) if the secondary channel is above the primary channel Set to 3 (SCB) if the secondary channel is below the primary channel Set to 0 (SCN) if no secondary channel is present The value 2 is reserved	N

Source: IEEE Standard 802.11n-2009 at 77.

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>
Table 20-5—Timing-related constants
<table>
<tr><th rowspan="3">Parameter</th><th colspan="4">TXVECTOR CH_BANDWIDTH</th></tr>
<tr><th rowspan="2">NON_HT_CBW20</th><th rowspan="2">HT_CBW_20</th><th colspan="2">HT_CBW40 or NON_HT_CBW40</th></tr>
<tr><th>HT format</th><th>MCS 32 and non-HT duplicate</th></tr>
<tr><td>N_{SD}: Number of complex data numbers</td><td>48</td><td>52</td><td>108</td><td>48</td></tr>
<tr><td>N_{SP}: Number of pilot values</td><td>4</td><td>4</td><td>6</td><td>4</td></tr>
<tr><td>N_{ST}: Total number of subcarriers
See NOTE 1</td><td>52</td><td>56</td><td>114</td><td>104</td></tr>
</table>
Source: IEEE Standard 802.11n-2009 at Table 20-5.
</td></tr>
</table>

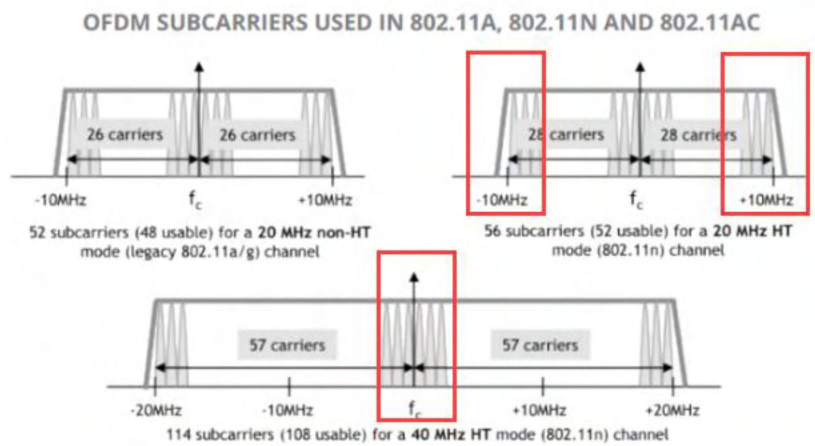
[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20.3.11.10.3 Transmission in 40 MHz HT format For 40 MHz HT transmissions, the signal from transmit chain i_{TX} shall be as shown in Equation (20-59). $$r_{HT-DATA}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-DATA}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} ([Q_k]_{i_{TX}, i_{STS}}(\tilde{D}_{k, i_{STS}, n} + p_{n+z}P_{(i_{STS}, n)}^{k})\Upsilon_k \cdot \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}}))) \quad (20\text{-}59)$$ 301

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	where z is 3 in an HT-mixed format packet and 2 in an HT-greenfield format packet p_n is defined in 17.3.5.9 $\tilde{D}_{k, i_{STS}, n} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ \tilde{d}_{M^r(k), i_{STS}, n}, \text{otherwise} \end{cases}$ $M^r(k) = \begin{cases} k + 58, -58 \le k \le -54 \\ k + 57, -52 \le k \le -26 \\ k + 56, -24 \le k \le -12 \\ k + 55, -10 \le k \le -2 \\ k + 52, 2 \le k \le 10 \\ k + 51, 12 \le k \le 24 \\ k + 50, 26 \le k \le 52 \\ k + 49, 54 \le k \le 58 \end{cases}$ $P^k_{(i_{STS}, n)}$ is defined in Equation (20-55) NOTE—The 90º rotation that is applied to the upper part of the 40 MHz channel is applied in the same way to the HT-STF, HT-LTF, and HT-SIG. The rotation applies to both pilots and the data in the upper part of the 40 MHz channel. Source: IEEE Standard 802.11n-2009 at 301-302. On information and belief, IEEE 802.11ac infringes for the same reasons as 802.11n. *See supra*. *See also*:

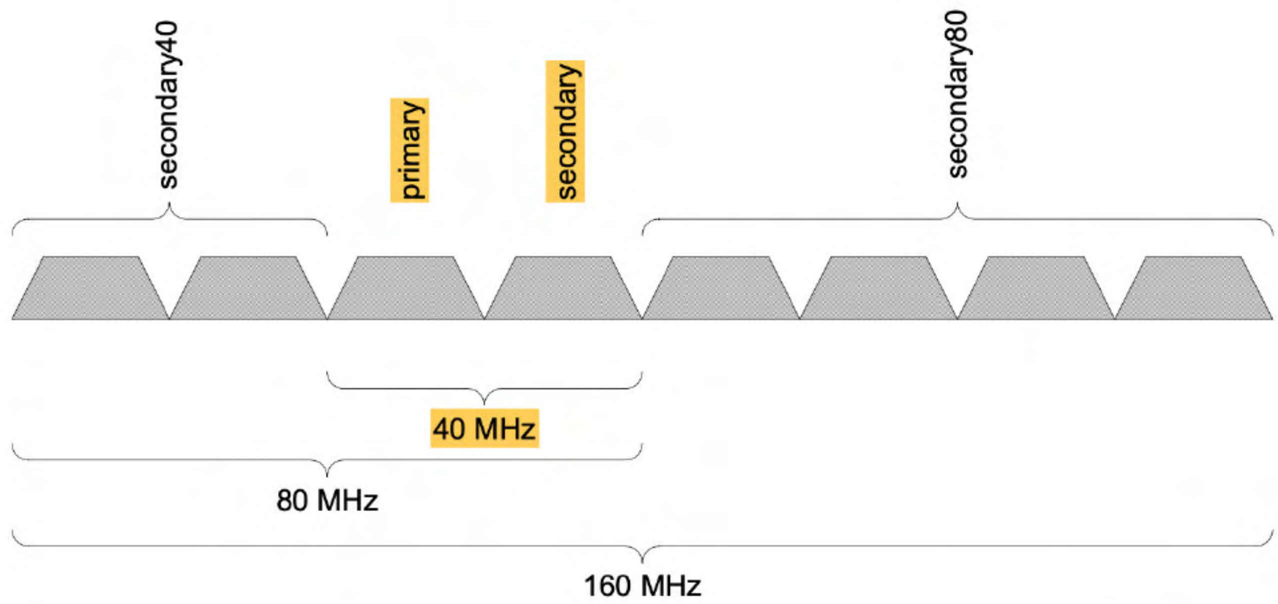
[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	 Source: https://www.cablefree.net/wirelesstechnology/802-11ac/. **3.2 Definitions specific to IEEE 802.11**

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	primary 20 MHz channel: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel that is used to transmit 20 MHz physical layer (PHY) protocol data units (PPDUs). In a VHT BSS, the primary 20 MHz channel is also the primary channel. **primary 40 MHz channel:** In an 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 40 MHz channel that is used to transmit 40 MHz physical layer (PHY) protocol data units (PPDUs). **primary 80 MHz channel:** In a 160 MHz or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 80 MHz channel that is used to transmit 80 MHz physical layer (PHY) protocol data units (PPDUs). **primary access category (AC):** The access category (AC) associated with the enhanced distributed channel access function (EDCAF) that gains channel access. **secondary 20 MHz channel**: In a 40 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel adjacent to the primary 20 MHz channel that together form the 40 MHz channel of the 40 MHz VHT BSS. In an 80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 80 MHz VHT BSS. In a 160 MHz or 80+80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 160 MHz or 80+80 MHz VHT BSS. In a VHT BSS, the secondary 20 MHz channel is also the secondary channel. **secondary channel**: A 20 MHz channel associated with a primary channel used by high-throughput (HT) stations (STAs) for the purpose of creating a 40 MHz channel or used by very high throughput (VHT) stations (STAs) for the purpose of creating the primary 40 MHz channel. **non-primary channel**: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), any 20 MHz channel other than the primary 20 MHz channel. Source: IEEE Standard 802.11ac-2013 at 2, 4, 7.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	 **Figure 7-1—The channel-list parameter element for 40 MHz, 80 MHz, and 160 MHz channel width** Source: IEEE Standard 802.11ac-2013 at 31.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	4.3.10a Very high throughput (VHT) STA This subclause summarizes the normative requirements for an IEEE 802.11 VHT STA stated elsewhere in this standard. The IEEE 802.11 VHT STA operates in frequency bands below 6 GHz excluding the 2.4 GHz band. A VHT STA is an HT STA that, in addition to features supported as an HT STA, supports VHT features identified in Clause 8, Clause 9, Clause 10, Clause 13, Clause 18, and Clause 22. The main PHY features in a VHT STA that are not present in an HT STA are the following: — Mandatory support for 40 MHz and 80 MHz channel widths — Mandatory support for VHT single-user (SU) PPDUs — Optional support for 160 MHz and 80+80 MHz channel widths — Optional support for VHT sounding protocol to support beamforming — Optional support for VHT multi-user (MU) PPDUs — Optional support for VHT-MCSs 8 and 9 Source: IEEE Standard 802.11ac-2013 at 10.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.5 Parameters for VHT-MCSs The rate-dependent parameters for 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz $N_{SS} = 1, \ldots, 8$ are given in Table 22-30 through Table 22-61. Support for 400 ns GI is optional in all cases. Support for VHT-MCS 8 and 9 (when valid) is optional in all cases. A VHT STA shall support single spatial stream VHT-MCSs within the range VHT-MCS 0 to VHT-MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported VHT-MCS and NSS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported VHT-MCS and NSS Set field may result in a reduced VHT-MCS range (cut-off) for $N_{SS} = 2, \ldots, 8$. Support for 20 MHz, 40 MHz, and 80 MHz with $N_{SS} = 1$ is mandatory. Support for 20 MHz, 40 MHz, and 80 MHz with $N_{SS} = 2, \ldots, 8$ is optional. Support for 160 MHz and 80+80 MHz with $N_{SS} = 1, \ldots, 8$ is optional. N_{ES} values were chosen to yield an integer number of punctured blocks for each BCC encoder per OFDM symbol. Table 22-30 to Table 22-33, Table 22-38 to Table 22-41, Table 22-46 to Table 22-49, and Table 22-54 to Table 22-57 define VHT-MCSs not only for SU transmission but also for user u of MU transmission. In the case of VHT-MCSs for MU transmission, the parameters, N_{SS}, R, N_{BPSCS}, N_{CBPS}, N_{DBPS}, and N_{ES} are replaced with $N_{SS,u}$, R_u, $N_{BPSCS,u}$, $N_{CBPS,u}$, $N_{DBPS,u}$, and $N_{ES,u}$, respectively. Source: IEEE Standard 802.11ac-2013 at 323.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	(table below)

Table 22-38—VHT-MCSs for mandatory 40 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	108	54	1	13.5	15.0
1	QPSK	1/2	2	108	6	216	108	1	27.0	30.0
2	QPSK	3/4	2	108	6	216	162	1	40.5	45.0
3	16-QAM	1/2	4	108	6	432	216	1	54.0	60.0
4	16-QAM	3/4	4	108	6	432	324	1	81.0	90.0
5	64-QAM	2/3	6	108	6	648	432	1	108.0	120.0
6	64-QAM	3/4	6	108	6	648	486	1	121.5	135.0
7	64-QAM	5/6	6	108	6	648	540	1	135.0	150.0
8	256-QAM	3/4	8	108	6	864	648	1	162.0	180.0
9	256-QAM	5/6	8	108	6	864	720	1	180.0	200.0

Source: IEEE Standard 802.11ac-2013 at 328.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Table 22-5—Timing-related constants

Parameter	CBW20	CBW40	CBW80	CBW80+80	CBW160	Description
N_{SD}	52	108	234	234	468	Number of complex data numbers per frequency segment
N_{SP}	4	6	8	8	16	Number of pilot values per frequency segment
N_{ST}	56	114	242	242	484	Total number of subcarriers per frequency segment. See NOTE.
N_{SR}	28	58	122	122	250	Highest data subcarrier index per frequency segment
N_{Seg}	1	1	1	2	1	Number of frequency segments
Δ_F	312.5 kHz					Subcarrier frequency spacing
T_{DFT}	3.2 μs					IDFT/DFT period

Source: IEEE Standard 802.11ac-2013 at Table 20-5.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.3.7.3 Channel frequencies Let $f_{c,\ \mathrm{idx0}} = \mathrm{dot11CurrentChannelCenterFrequencyIndex0}$ (22-1) $f_{c,\ \mathrm{idx1}} = \mathrm{dot11CurrentChannelCenterFrequencyIndex1}$ (22-2) $f_{\mathrm{P20,\ idx}} = \mathrm{dot11CurrentPrimaryChannel}$ (22-3) $f_{\mathrm{CH,\ start}} = \mathrm{dot11ChannelStartingFactor} \times 500\ \mathrm{kHz}$ (22-4) where dot11CurrentChannelCenterFrequencyIndex0, dot11CurrentChannelCenterFrequencyIndex1, and dot11CurrentPrimaryChannel are defined in Table 22-22. When dot11CurrentChannelWidth (see Table 22-22) is 20 MHz, $f_{\mathrm{P20,\ idx}} = f_{c,\ \mathrm{idx0}}$. For dot11CurrentChannelWidth greater than 20 MHz, $f_{\mathrm{P20,\ idx}}$ and $f_{c,\ \mathrm{idx0}}$ shall have the relationship specified in Equation (22-5). $f_{\mathrm{P20,\ idx}} = f_{c,\ \mathrm{idx0}} - 4 \cdot \left(\frac{N_{20\mathrm{MHz}}}{2} - n_{\mathrm{P20}}\right) + 2$ (22-5) where $N_{20\mathrm{MHz}} = \begin{cases} 2, \text{ if dot11CurrentChannelWidth indicates 40 MHz} \\ 4, \text{ if dot11CurrentChannelWidth indicates 80 MHz and 80+80 MHz} \\ 8, \text{ if dot11CurrentChannelWidth indicates 160 MHz} \end{cases}$ Source: IEEE Standard 802.11ac-2013 at 248.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.3.7.4 Transmitted signal The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (22-11). $$r_{RF}^{(i_{Seg},\, i_{TX})}(t) = \mathrm{Re}\left\{ \frac{1}{\sqrt{N_{Seg}}} r_{\mathrm{PPDU}}^{(i_{Seg},\, i_{TX})}(t) \exp(j2\pi f_c^{(i_{Seg})} t) \right\}, \quad (22\text{-}11)$$ $$i_{Seg} = 0, \ldots, N_{Seg} - 1; \quad i_{TX} = 1, \ldots, N_{TX}$$ where $\mathrm{Re}\{.\}$ represents the real part of a complex variable; N_{Seg} represents the number of frequency segments in the transmit signal, as defined in Table 22-5; $r_{\mathrm{PPDU}}^{(i_{Seg},\, i_{TX})}(t)$ represents the complex baseband signal of frequency segment i_{Seg} in transmit chain i_{TX}; $f_c^{(i_{Seg})}$ represents the center frequency of the portion of the PPDU transmitted in frequency segment i_{Seg}. Table 22-7 shows $f_c^{(i_{Seg})}$ as a function of the channel starting frequency and dot11CurrentChannelWidth (see Table 22-22) where $f_{\mathrm{P20,\,idx}}$, $f_{\mathrm{P40,\,idx}}$, and $f_{\mathrm{P80,\,idx}}$ are given in Equation (22-4), Equation (22-5), Equation (22-7), and Equation (22-9), respectively. NOTE—Transmitted signals may have different impairments such as phase offset or phase noise between the two frequency segments, which is not shown in Equation (22-11) for simplicity. See 22.3.18.3. Source: IEEE Standard 802.11ac-2013 at 249.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Table 8-53g—Subcarriers for which a Compressed Beamforming Feedback Matrix subfield is sent back

Channel Width	*Ng*	*Ns*	Subcarriers for which Compressed Feedback Beamforming Matrix subfield is sent: *scidx*(0), *scidx*(1), ..., *scidx*(*Ns*-1)
20 MHz	1	52	–28, –27, –26, –25, –24, –23, –22, –20, –19, –18, –17, –16, –15, –14, –13, –12, –11, –10, –9, –8, –6, –5, –4, –3, –2, –1, 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28 NOTE—Pilot subcarriers (±21, ±7) and DC subcarrier (0) are skipped
	2	30	–28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28
	4	16	–28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28
40 MHz	1	108	–58, –57, –56, –55, –54, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58 NOTE—Pilot subcarriers (±53, ±25, ±11) and DC subcarriers (0, ±1) are skipped.
	2	58	–58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, -22, –20, –18, –16, –14, –12, –10, –8, –6, –4,–2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58
	4	30	–58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6,–2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58

Source: IEEE Standard 802.11ac-2013 at 59.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Table 8-53j—Number of subcarriers and subcarrier mapping (table below) Source: IEEE Standard 802.11ac-2013 at 66.

Table 8-53j—Number of subcarriers and subcarrier mapping

Channel Width	*Ng*	*Ns′*	Subcarriers for which the Delta SNR subfield is sent: *sscidx*(0), *sscidx*(1), … *sscidx*(*Ns′*–1)
20 MHz	1	30	–28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28
	2	16	–28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28
	4	10	–28, –20, –12, –4, –1, 1, 4, 12, 20, 28
40 MHz	1	58	–58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4,–2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58
	2	30	–58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6,–2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58
	4	16	–58, –50, –42, –34, –26, –18, –10, –2, 2, 10, 18, 26, 34, 42, 50, 58

Source: IEEE Standard 802.11ac-2013 at 66.

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>
Table 10-19—VHT BSS operating channel width
<table>
<tr><th>HT Operation element STA Channel Width field</th><th>VHT Operation element Channel Width field</th><th>BSS operating channel width</th></tr>
<tr><td>0</td><td>0</td><td>20 MHz</td></tr>
<tr><td>1</td><td>0</td><td>40 MHz</td></tr>
<tr><td>1</td><td>1</td><td>80 MHz</td></tr>
<tr><td>1</td><td>2</td><td>160 MHz</td></tr>
<tr><td>1</td><td>3</td><td>80+80 MHz</td></tr>
</table>
Source: IEEE Standard 802.11ac-2013 at 186.
</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	21.3.10.10 Pilot subcarriers In a 20 MHz transmission, four pilot tones shall be inserted in subcarriers $k \in \{-21, -7, 7, 21\}$. The pilot mapping P_n^k for subcarrier k for symbol n shall be as specified in Equation (21-91). $P_n^{\{-21,-7,7,21\}} = \{\Psi_{1,n \bmod 4}^{\{1\}}, \Psi_{1,(n+1) \bmod 4}^{\{1\}}, \Psi_{1,(n+2) \bmod 4}^{\{1\}}, \Psi_{1,(n+3) \bmod 4}^{\{1\}}\}$ $P_n^{k \notin \{-21,-7,7,21\}} = 0$ (21-91) where $\Psi_{1,m}^{\{1\}}$ is given by the $N_{STS} = 1$ row of Table 19-19 In a 40 MHz transmission, six pilot tones shall be inserted in subcarriers –53, –25, –11, 11, 25, and 53. The pilot mapping P_n^k for subcarrier k for symbol n shall be as specified in Equation (21-92). Source: IEEE Standard 802.11-2016 at 2574.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	(Table 9-70 below)

Table 9-70—Subcarriers for which a Compressed Beamforming Feedback Matrix subfield is sent back

Channel Width	*Ng*	*Ns*	Subcarriers for which Compressed Feedback Beamforming Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1)
20 MHz	1	52	–28, –27, –26, –25, –24, –23, –22, –20, –19, –18, –17, –16, –15, –14, –13, –12, –11, –10, –9, –8, –6, –5, –4, –3, –2, –1, 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28 NOTE—Pilot subcarriers (±21, ±7) and DC subcarrier (0) are skipped
	2	30	–28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28
	4	16	–28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28
40 MHz	1	108	–58, –57, –56, –55, –54, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58 NOTE—Pilot subcarriers (±53, ±25, ±11) and DC subcarriers (0, ±1) are skipped.
	2	58	–58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, -22, –20, –18, –16, –14, –12, –10, –8, –6, –4,–2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58
	4	30	–58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6,–2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58
80 MHz	1	234	–122, –121, –120, –119, –118, –117, –116, –115, –114, –113, –112, –111, –110, –109, –108, –107, –106, –105, –104, –102, –101, –100, –99, –98, –97, –96, –95, –94, –93, –92, –91, –90, –89, –88, –87, –86, –85, –84, –83, –82, –81, –80, –79, –78, –77, –76, –74, –73, –72, –71, –70, –69, –68, –67, –66, –65, –64, –63, –62, –61, –60, –59, –58, –57, –56, –55, –54, –53, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –25, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122 NOTE—Pilot subcarriers (±103, ±75, ±39, ±11) and DC subcarriers (0, ±1) are skipped.

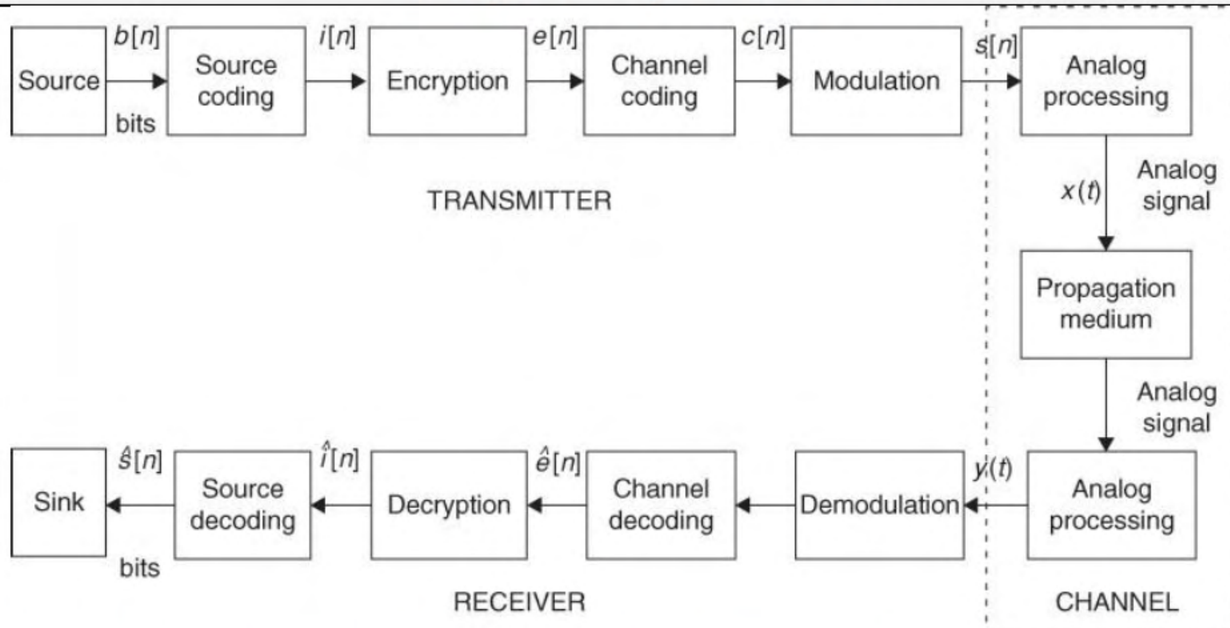
[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>
Source: IEEE Standard 802.11-2016 at 768.
<table>
<tr><td rowspan="2">EXPANSION_MAT_TYPE</td><td>FORMAT is VHT and EXPANSION_MAT is present.</td><td>Set to COMPRESSED_SV</td><td>Y</td><td>N</td></tr>
<tr><td>Otherwise</td><td colspan="3">See corresponding entry in Table 19-1</td></tr>
<tr><td rowspan="2">EXPANSION_MAT</td><td>FORMAT is VHT</td><td>Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 21.3.11.2 based on the channel measured during the training symbols of a previous VHT NDP PPDU.</td><td>MU</td><td>N</td></tr>
<tr><td>Otherwise</td><td colspan="3">See corresponding entry in Table 19-1</td></tr>
</table>
Source: IEEE Standard 802.11-2016 at 2501.

On information and belief, digital signal processing is needed for a digital system to process that waveform. See, e.g., R. Heath, “Introduction to Wireless Digital Communication” (2017), Figure 2.1.
</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	See below



On information and belief, a digital system samples the continuous time waveform at discrete points in time, forming a discrete-time version of a waveform. IEEE 802.11n-2009 standard describes that FFT and IFFT structures scale by the number of transmit chains, as seen in the two transmitter block diagrams 1 and 2 in Figures 20-2 and 20-3.

4. Abbreviations and acronyms

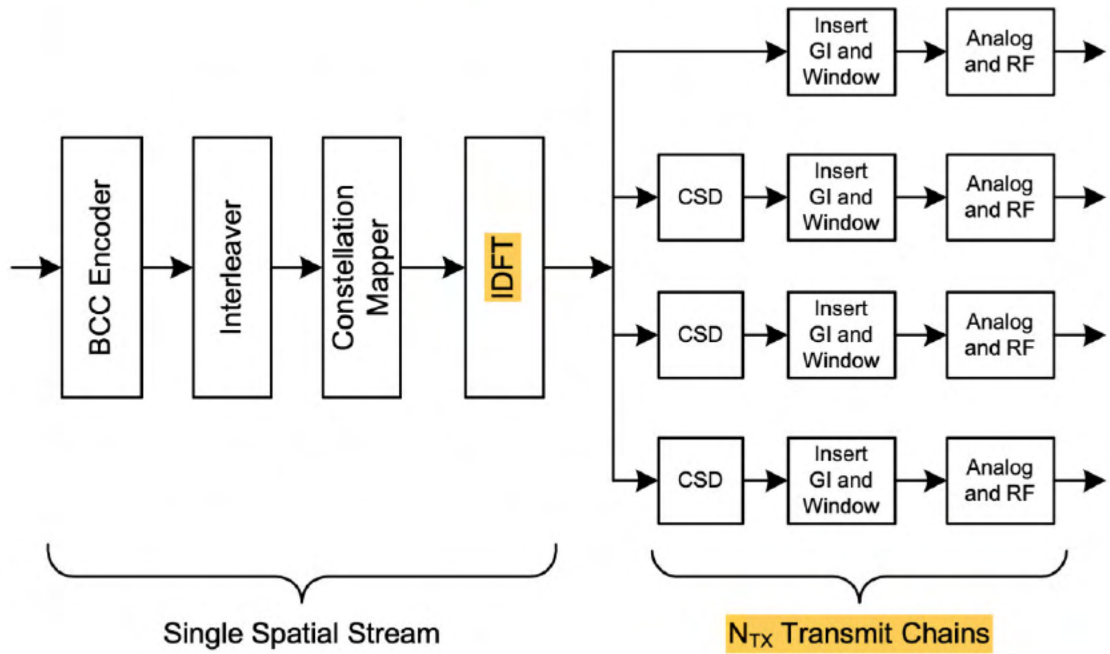
IDFT inverse discrete Fourier transform

Source: IEEE Standard 802.11n-2009 at 9.

[redacted]

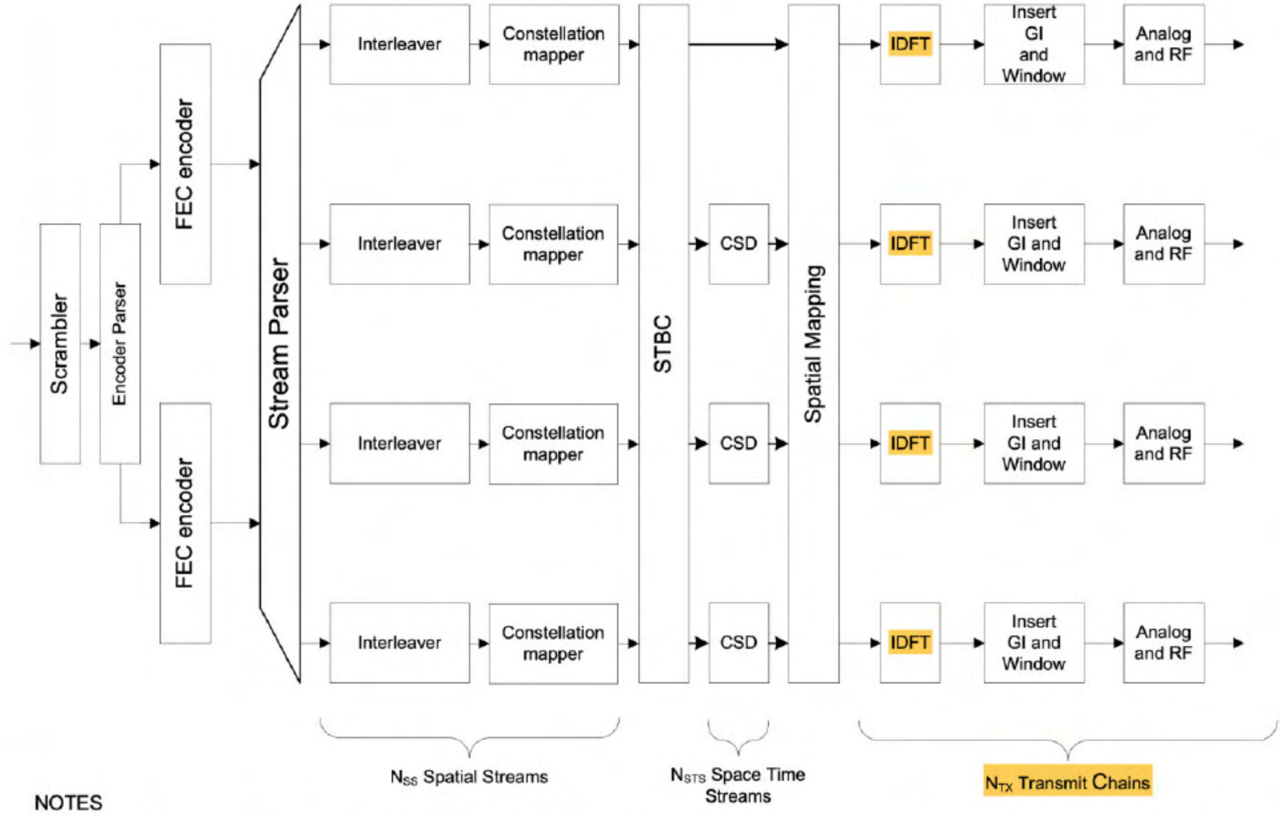
U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20.3.3 Transmitter block diagram Figure 20-2 and Figure 20-3 show example transmitter block diagrams. In particular, Figure 20-2 shows the transmitter blocks used to generate the HT-SIG of the HT-mixed format PPDU. These transmitter blocks are also used to generate the non-HT portion of the HT-mixed format PPDU, except that the BCC encoder and interleaver are not used when generating the L-STF and L-LTFs. Figure 20-3 shows the transmitter blocks used to generate the Data field of the HT-mixed format and HT-greenfield format PPDUs. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right of, and including, the spatial mapping block, are also used to generate the HT-STF, HT-GF-STF, and HT-LTFs. The HT-greenfield format SIGNAL field is generated using the transmitter blocks shown in Figure 20-2, augmented by additional CSD and spatial mapping blocks.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	 **Figure 20-2—Transmitter block diagram 1** Source: IEEE Standard 802.11n-2009 at 261.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	Example Viasat Systems and Services



NOTES
—There may be 1 or 2 FEC encoders when BCC encoding is used.
—The stream parser may have 1, 2, 3 or 4 outputs.
—When LDPC encoding is used, the interleavers are not used
—When STBC is used, the STBC block has more outputs than inputs.
—When spatial mapping is used, there may be more transmit chains than space time streams.
—The number of inputs to the spatial mapper may be 1, 2, 3, or 4.

Figure 20-3—Transmitter block diagram 2

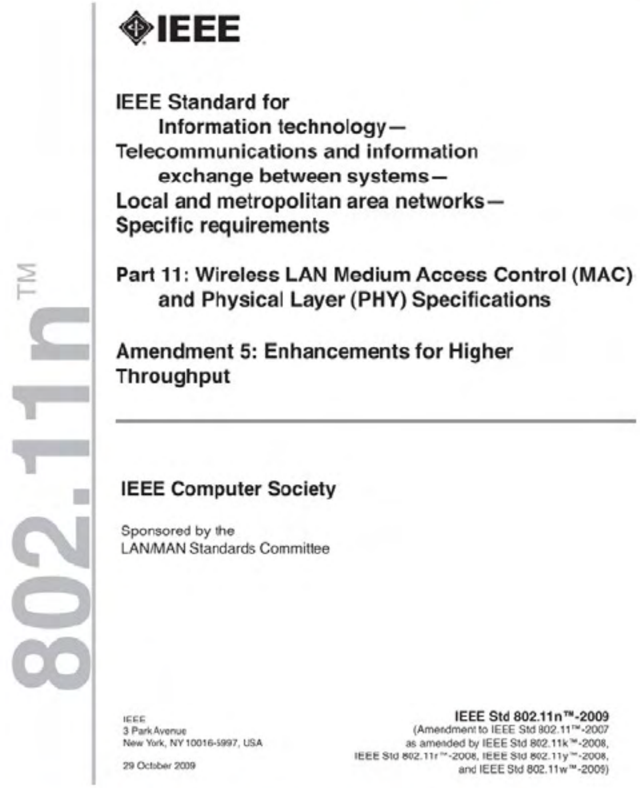
Source: IEEE Standard 802.11n-2009 at 262.

On information and belief, the HT PHY uses a 128-point IDFT, usually implemented as an IFFT, to create the transmitted signal across the full 40 MHz signal spectrum. This process involves a fast fourier

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	transform (FFT). For transmitters and receivers to operate on that signal, there is digital signal processing or DSP. *See supra*. Section 20.3.7 of IEEE 802.11n-2009 has a section that includes a description of the convention on mathematical description of signals and refers to Section 17.3.2.4, which refers back to a prior version of 802.11. **20.3.7 Mathematical description of signals** For the description of the convention on mathematical description of signals, see 17.3.2.4. In the case of either a 20 MHz non-HT format (TXVECTOR parameter FORMAT set to NON_HT, MODULATION parameter set to one of {DSSS-OFDM, ERP-OFDM, OFDM}) transmission or a 20 MHz HT format (TXVECTOR parameter FORMAT set to HT_MF or HT_GF, CH_BANDWIDTH set to HT_CBW_20) transmission, the channel is divided into 64 subcarriers. In the 20 MHz non-HT format, the signal is transmitted on subcarriers –26 to –1 and 1 to 26, with 0 being the center (dc) carrier. In the 20 MHz HT format, the signal is transmitted on subcarriers –28 to –1 and 1 to 28. In the case of the 40 MHz HT format, a 40 MHz channel is used. The channel is divided into 128 subcarriers. The signal is transmitted on subcarriers –58 to –2 and 2 to 58. Source: IEEE Standard 802.11n-2009 at 267. Section 17.3.2.4 is not included in IEEE 802.11n-2009 but is included in the previous iteration of IEEE 802.11, IEEE 802.11-2007.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	 IEEE 802.11n™ IEEE Standard for Information technology— Telecommunications and information exchange between systems— Local and metropolitan area networks— Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 5: Enhancements for Higher Throughput IEEE Computer Society Sponsored by the LAN/MAN Standards Committee IEEE 3 Park Avenue New York, NY 10016-5997, USA 29 October 2009 IEEE Std 802.11n™-2009 (Amendment to IEEE Std 802.11™-2007 as amended by IEEE Std 802.11k™-2008, IEEE Std 802.11r™-2008, IEEE Std 802.11y™-2008, and IEEE Std 802.11w™-2009) Source: IEEE Standard 802.11n-2009 at 1. In Section 17.3.2.4, the discussion assumes the use of OFDM, FFTs, and IFFTs.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	17.3.2.4 Mathematical conventions in the signal descriptions The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μs for 20 MHz channel spacing, 32 μs for 10 MHz channel spacing, and 64 μs for 5 MHz channel spacing, and t_{DATA} is equal to 20 μs for 20 MHz channel spacing, 40 μs for 10 MHz channel spacing, and 80 μs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Source: IEEE Standard 802.11-2007 at 598. Section 17.3.2.5 describes discrete time implementation considerations and how these continuous-time equations are related to discrete time systems that run the 802.11 protocol:

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	17.3.2.5 Discrete time implementation considerations The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

$$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0,\ 80 \\ 0 & otherwise \end{cases} \qquad (17\text{-}5)$$

The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.

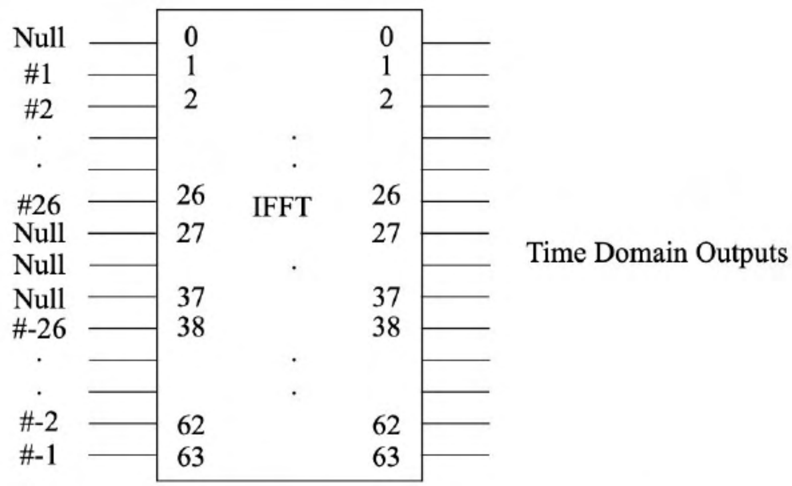
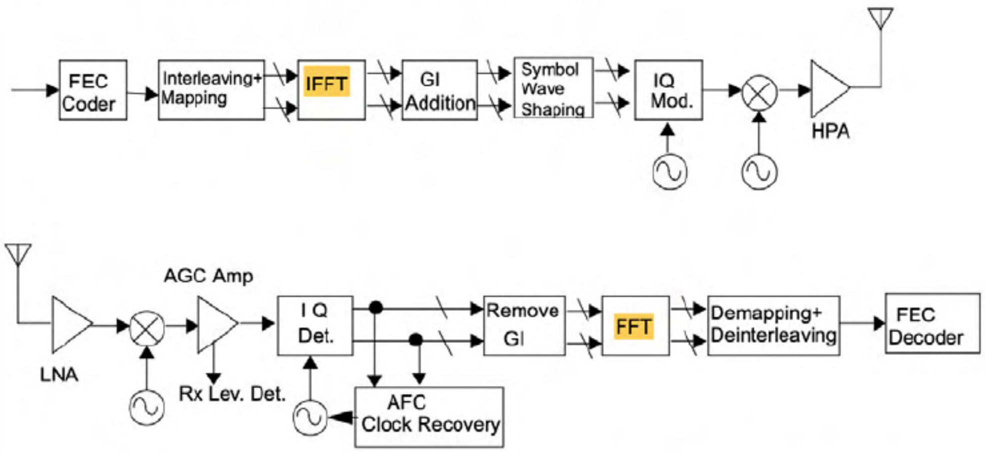


Figure 17-3—Inputs and outputs of inverse Fourier transform

See IEEE 802.11-2007, pages 599-600.

Section 17.3.8 describes a transmitter and receiver for the OFDM PHY, which includes IFFTs and FFTs.

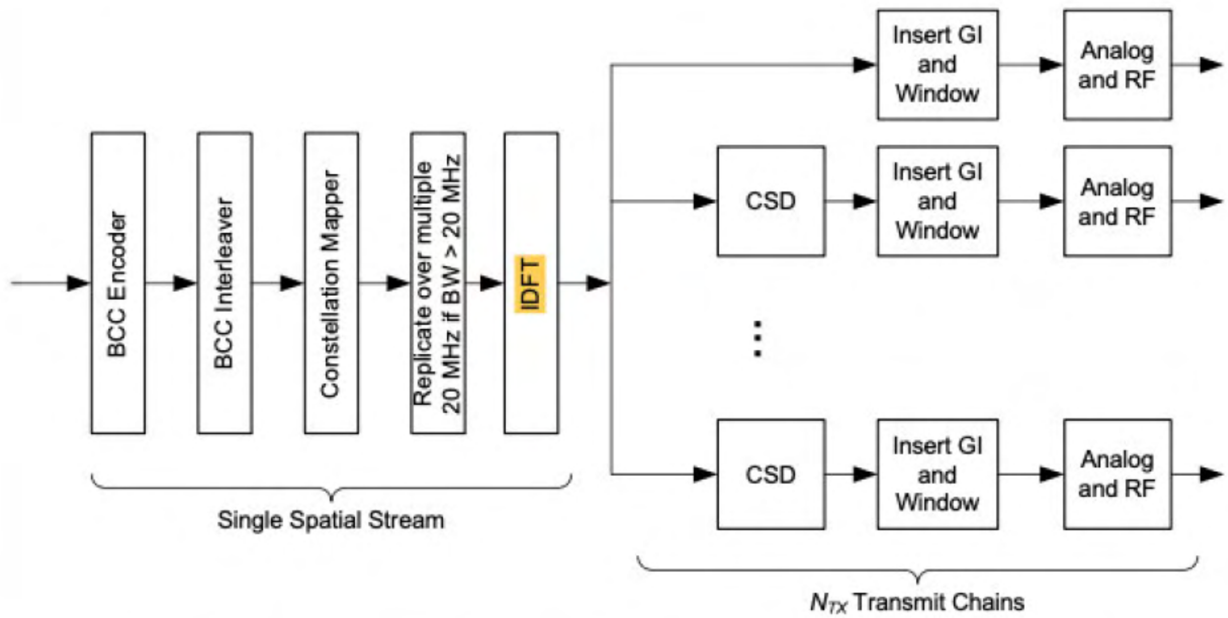
[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	17.3.8 PMD operating specifications (general) General specifications for the BPSK OFDM, QPSK OFDM, 16-QAM OFDM, and 64-QAM OFDM PMD sublayers are provided in 17.3.8.1 through 17.3.8.8. These specifications apply to both the receive and transmit functions and general operation of the OFDM PHY. **17.3.8.1 Outline description** The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.  **Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY** See IEEE 802.11-2007 at 612. On information and belief, IEEE 802.11ac infringes for the same reasons as 802.11n. *See supra*. *See also*:

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.3.3 Transmitter block diagram The generation of each field in a VHT PPDU uses many of the following blocks: a) PHY padding b) Scrambler c) BCC encoder parser d) FEC (BCC or LDPC) encoders e) Stream parser f) Segment parser (for contiguous 160 MHz and noncontiguous 80+80 MHz transmissions) g) BCC interleaver h) Constellation mapper i) Pilot insertion j) Replicate over multiple 20 MHz (if BW > 20 MHz) k) Multiply by 1st column of P_{VHTLTF} l) LDPC tone mapper m) Segment deparser n) Space time block code (STBC) encoder o) Cyclic shift diversity (CSD) per STS insertion p) Spatial mapper q) Inverse discrete Fourier transform (IDFT) r) Cyclic shift diversity (CSD) per chain insertion s) Guard interval (GI) insertion t) Windowing Source: IEEE Standard 802.11ac-2013 at 230.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Figure 22-5 to Figure 22-16 show example transmitter block diagrams. The actual structure of the transmitter is implementation dependent. In particular, Figure 22-5 shows the transmit process for the L-SIG and VHT-SIG-A fields of a VHT PPDU using one frequency segment. These transmit blocks are also used to generate the non-VHT modulated fields of the VHT PPDU, except that the BCC encoder and interleaver are not used when generating the L-STF and L-LTF fields.  **Figure 22-5—Transmitter block diagram for the L-SIG and VHT-SIG-A fields** Source: IEEE Standard 802.11ac-2013 at 231.

[redacted]

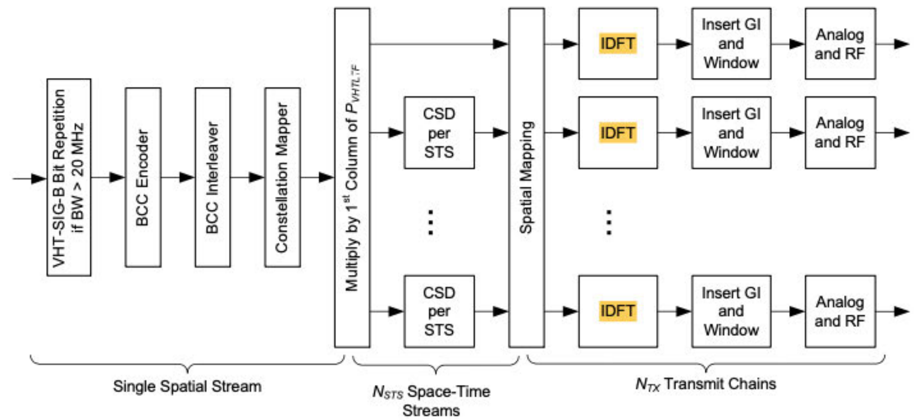


Figure 22-6—Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT SU PPDU

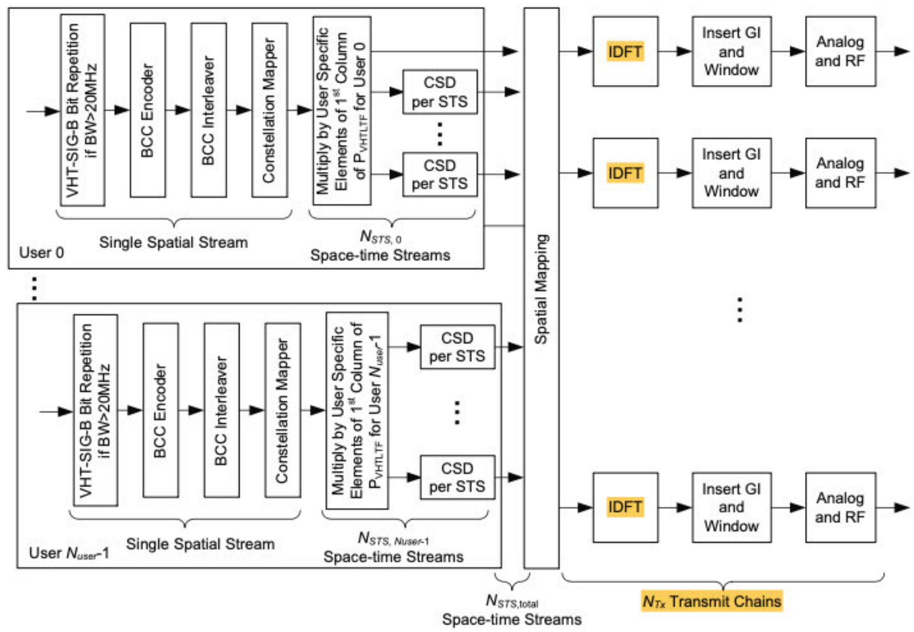


Figure 22-7—Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT MU PPDU

Source: IEEE Standard 802.11ac-2013 at 232.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	(see below)

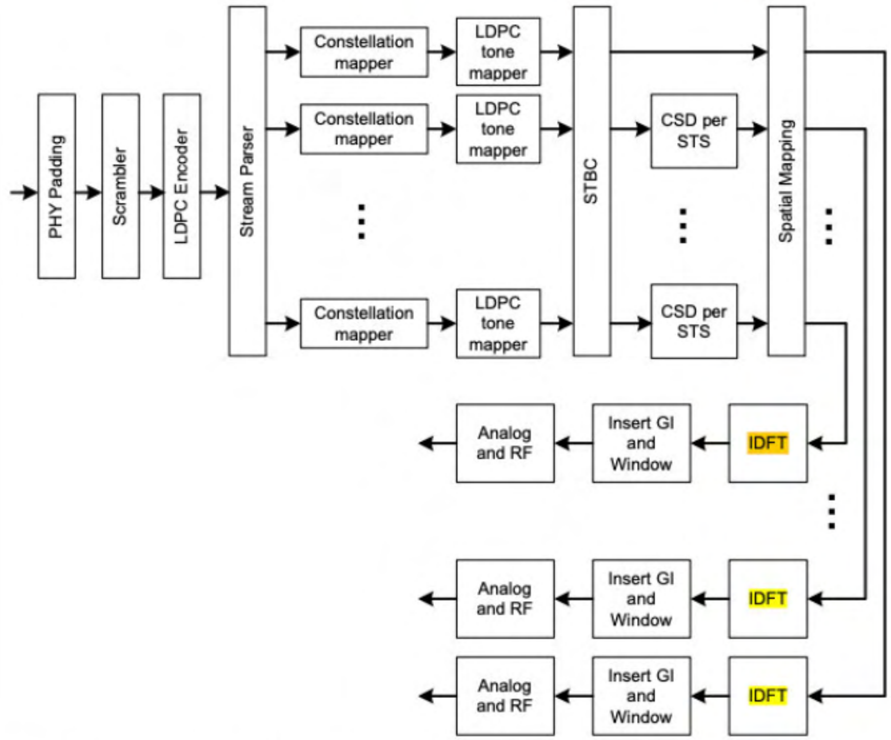


Figure 22-11—Transmitter block diagram for the Data field of a 20 MH, 40 MHz, or 80 MHz VHT SU PPDU with LDPC encoding

22.3.4.3 Construction of the L-LTF

Construct the L-LTF field as defined in 22.3.8.2.3 with the following highlights:

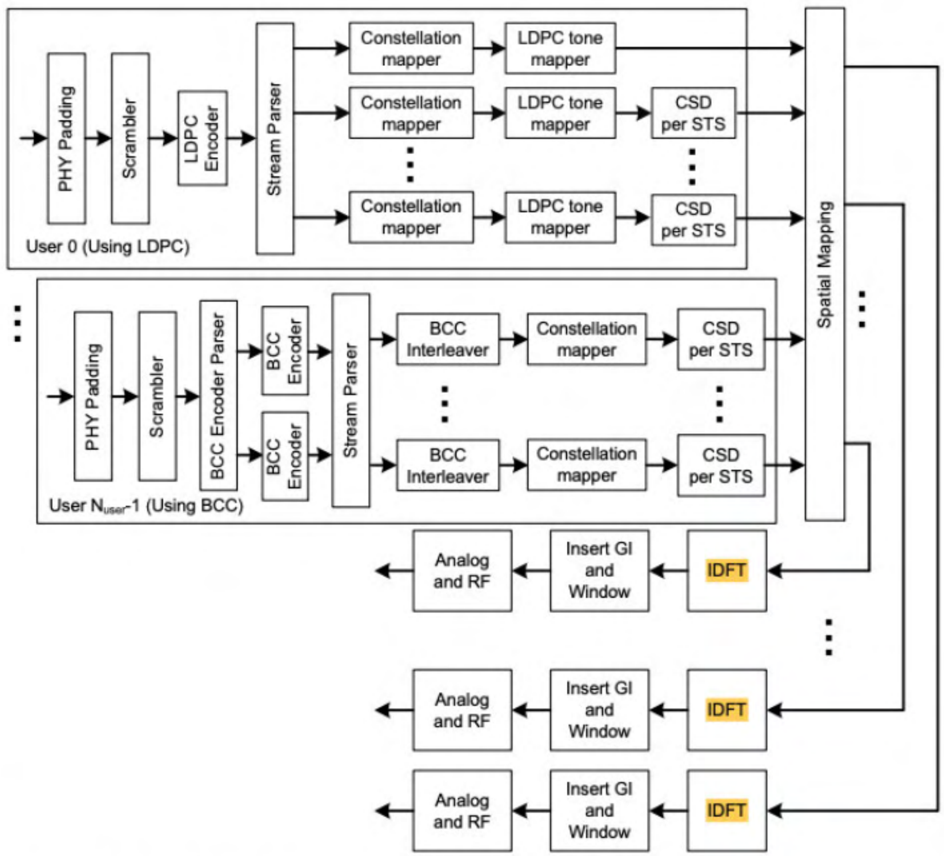
a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the L-LTF sequence over the CH_BANDWIDTH as described in 22.3.8.2.3.

c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 22.3.7.4 and 22.3.7.5.

d) IDFT: Compute the inverse discrete Fourier transform.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Source: IEEE Standard 802.11ac-2013 at 235.  **Figure 22-12—Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT MU PPDU** Source: IEEE Standard 802.11ac-2013 at 236. On information and belief, the HT PHY uses a 128-point IDFT, usually implemented as an IFFT, to create the transmitted signal across the full 40 MHz signal spectrum and involves a fast fourier

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	transform (FFT). For transmitters and receivers to operate on that signal, there is digital signal processing or DSP. Section 22.3.7 includes a description of conventions used for the mathematical description of signals, referring to Section 18.3.2.5. That section refers back to a prior version of 802.11. **22.3.7 Mathematical description of signals** **22.3.7.1 Notation** For a description of the conventions used for the mathematical description of the signals, see 18.3.2.5. In addition, the following notational conventions are used in Clause 22: $[Q]_{m,n}$ indicates the element in row m and column n of matrix Q, where $1 \le m \le N_{row}$ and $1 \le n \le N_{col}$ N_{row} and N_{col} are the number of rows and columns, respectively, of the matrix Q $[Q]_{M:N}$ indicates a matrix consisting of columns M to N of matrix Q Source: IEEE Standard 802.11ac-2013 at 247. Section 18.3.2.5 is not included in IEEE 802.11ac-2013, but the previous iteration of IEEE 802.11, IEEE 802.11-2012, includes Section 18.3.2.5.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	IEEE Standard for Information technology— Telecommunications and information exchange between systems Local and metropolitan area networks— Specific requirements **Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications** **Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz** IEEE Computer Society Sponsored by the LAN/MAN Standards Committee IEEE 3 Park Avenue New York, NY 10016-5997 USA IEEE Std 802.11ac™-2013 (Amendment to IEEE Std 802.11™-2012, as amended by IEEE Std 802.11ae™-2012, IEEE Std 802.11aa™-2012, and IEEE Std 802.11ad™-2012) Source: IEEE Standard 802.11-2012 at 1. Section 18.3.2.5 includes a discussion of the use of OFDM, FFTs, and IFFTs.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

18.3.2.5 Mathematical conventions in the signal descriptions

The transmitted signals are described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}\langle t\rangle = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\} \quad (18\text{-}1)$$

where

$Re(.)$ represents the real part of a complex variable

f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \quad (18\text{-}2)$$

The subframes of which Equation (18-2) are composed are described in 18.3.3, 18.3.4, and 18.3.5.10. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 18.3.3 to 18.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \quad (18\text{-}3)$$

The parameters Δ_F and N_{ST} are described in Table 18-5. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the

previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 18-5.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 18-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (18-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Source: IEEE Standard 802.11-2012 at 1591-1592.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Section 18.3.2.6 describes discrete time implementation considerations including how these continuous-time equations are related to discrete time systems that run the 802.11 protocol.

18.3.2.6 Discrete time implementation considerations

The following descriptions of the discrete time implementation are informational.

In a typical implementation, the windowing function is represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

$$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0,\ 80 \\ 0 & otherwise \end{cases} \qquad (18\text{-}5)$$

The common way to implement the inverse Fourier transform, as shown in Equation (18-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 18-3. After performing an IFFT, the output is cyclically extended to the desired length.

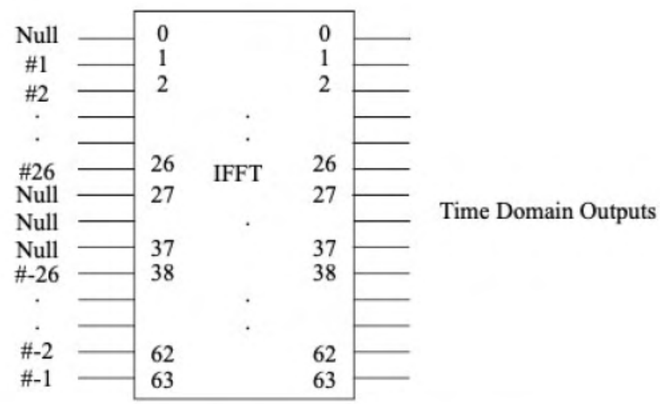


Figure 18-3—Inputs and outputs of inverse Fourier transform

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	See IEEE 802.11-2012, pages 1593.

Section 18.3.8 describes the transmitter and receiver for the OFDM PHY, which includes IFFTs and FFTs.

18.3.8 PMD operating specifications (general)

18.3.8.1 General

General specifications for the BPSK OFDM, QPSK OFDM, 16-QAM OFDM, and 64-QAM OFDM PMD sublayers are provided in 18.3.8.2 to 18.3.8.8. These specifications apply to both the receive and transmit functions and general operation of the OFDM PHY.

18.3.8.2 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 18-12. Major specifications for the OFDM PHY are listed in Table 18-12.

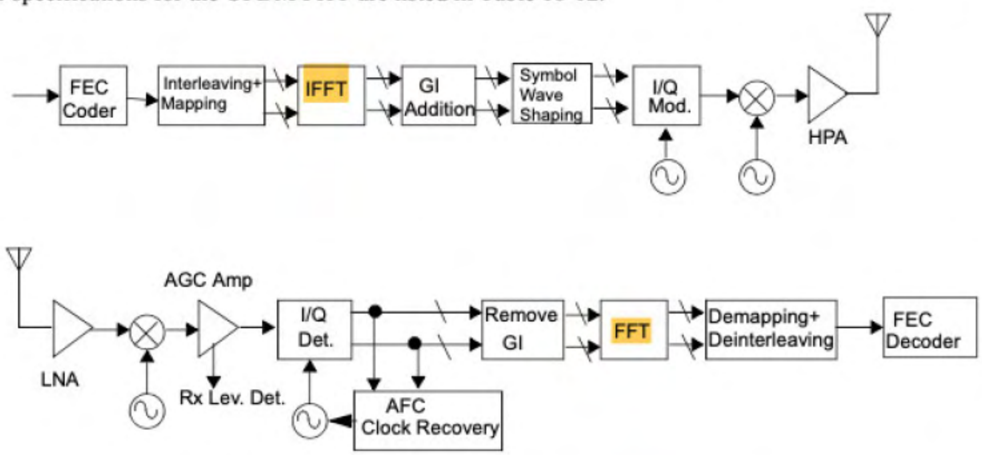
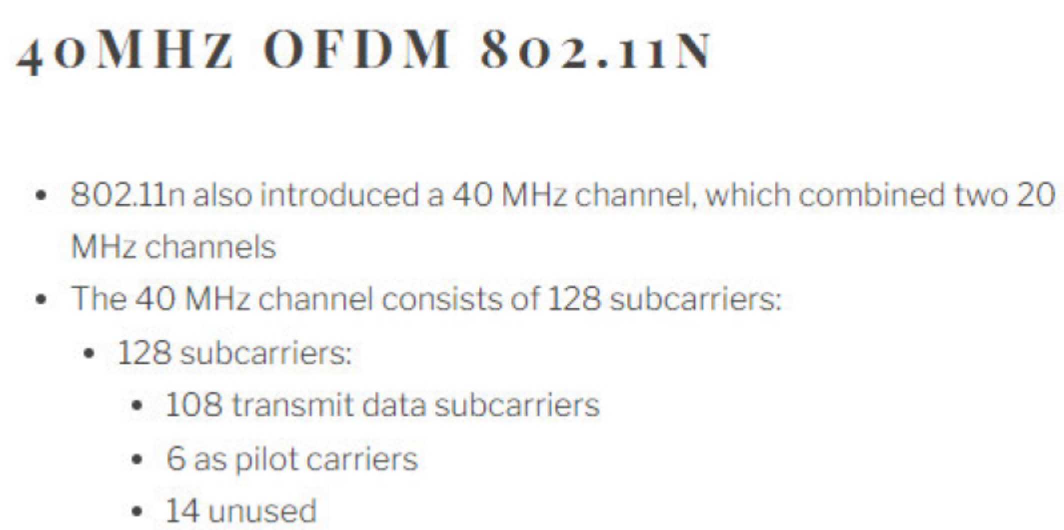


Figure 18-12—Transmitter and receiver block diagram for the OFDM PHY

See IEEE 802.11-2012, pages 1605.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
[1.c] combining the first channel and the second channel using channel bonding with orthogonal frequency division multiplexing (OFDM); and	On information and belief, the Viasat Systems and Services practice combining the first channel and the second channel using channel bonding with orthogonal frequency division multiplexing (OFDM). On information and belief, in 40 MHz capable HT STA, both primary ("first") and secondary ("second") 20 MHz channels are combined by using channel bonding to give a wideband channel. 

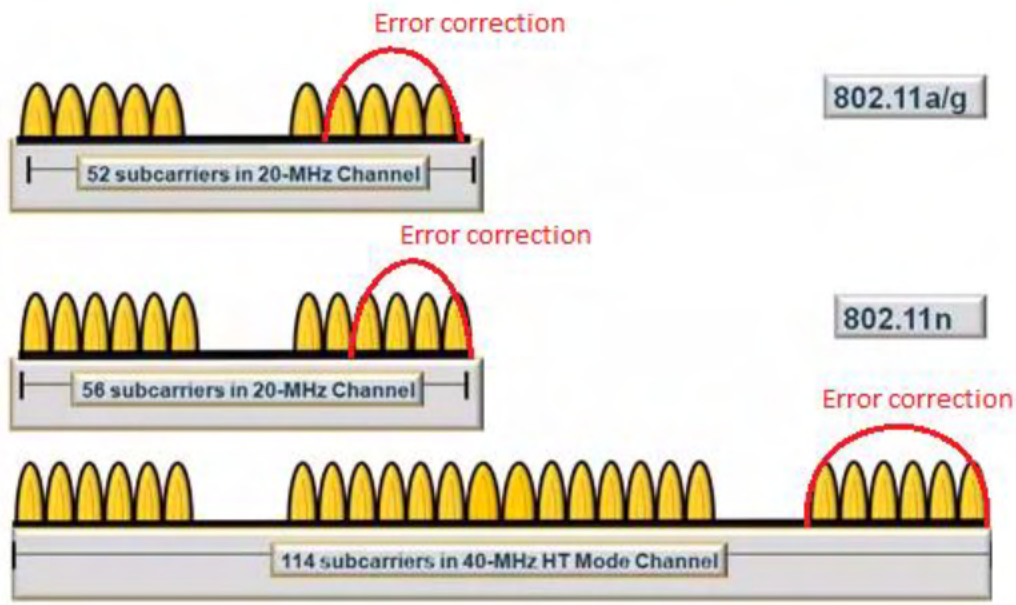
[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	• When two 20 MHz HT channels are bonded together, some of the formerly unused subcarriers at the bottom of the higher channel and at the top end of the lower channel are able to be used to transmit data. • That is why the number of subcarriers is slightly more than two times the 56 subcarriers in a 20 MHz channel. • Each bonded channel consists of a primary and secondary 20 MHz channel. • The channels must be adjacent. A positive or negative offset indicates whether the secondary channel is the channel above or the channel below the primary channel. This is pictured in Figure 19.4. Source: https://dot11ap.wordpress.com/ht-channel-width-operation/. Improved OFDM and Channel Bonding

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	802.11n uses a more efficient OFDM modulation and can use 40 MHz channels. This more than doubles the data rate for 802.11n when compared to 20 MHz channels. When operating within a traditional 20 MHz channel, OFDM further slices the channel into 52 subcarriers (48 of which are used for carrying data). However, when 802.11n applies OFDM on a 40 MHz channel, the number of data-carrying subcarriers do not simply double to 96 sub-carriers. Instead, they actually more than double to 114 subcarriers, including pilots (which do not carry data). This allows 802.11n to deliver a 65 Mbps data rate (instead of 54 Mbps) per 20 MHz channel for a total of 135 Mbps on a 40 MHz channel when transmitting a single spatial data stream. When transmitting using 2 spatial streams on a 40 MHz channel, this data rate again doubles to 135 Mbps x 2 — 270 Mbps. Source: https://www.winncom.com/images/stories/Motorola_802.11nDEM_WP_v4_0209.pdf. HT-OFDM 802.11a and g used Orthogonal Frequency Division Multiplexing (OFDM) to transmit information. 802.11n continues to use OFDM but in a slightly different way. This new version is called HT-OFDM for High Throughput OFDM. How does OFDM works? The OFDM divides a channel into several subcarriers to carry information. For example, 802.11a and g use an OFDM that divides the 20MHz channels into 52 subcarriers. 48 of those are used for data transmission and 4 others are used for forward error correction. This configuration offers a data rates of 54 Mbps at best. When 802.11n uses 20MHz channels, HT-OFDM now offers 56 subcarriers. There are still 4 that are used for forward error correction and now 52 that are used for data transmission. This marginally increases the data rates to a maximum of 65 Mbps. This is when we use a single-transmitter radio. For two transmitters, the maximum data rates is 130 Mbps. Three transmitters provide a maximum data rates of 195 Mbps. The maximum four transmitters can deliver 260 Mbps. When a 40MHz channel is used, we get 108 subcarriers to transmit data information and 6 subcarriers for forward error correction. This way the channel is divided into 114 subcarriers. This provides a maximum data rates of 135 Mbps, 270 Mbps, 405 Mbps, and 540 Mbps for one through four transmitters, respectively. Source: https://www.gta.ufrj.br/ensino/eel879/trabalhos_vf_2014_2/remi/Physical%20Layer%20Improvements.html.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	 Figure 10: Number of subcarriers offered by OFDM Source: https://www.gta.ufrj.br/ensino/eel879/trabalhos_vf_2014_2/remi/Physical%20Layer%20Improvements.html. This is also described in IEEE 802.11n-2009: **20. High Throughput (HT) PHY specification**

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20.1 Introduction **20.1.1 Introduction to the HT PHY** Clause 20 specifies the PHY entity for a high throughput (HT) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements found in Clause 20, an HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows: — In Clause 17 when the HT STA is operating in a 20 MHz channel width in the 5 GHz band — In Clause 18 and Clause 19 when the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band The HT PHY is based on the OFDM PHY defined in Clause 17, with extensibility up to four spatial streams, operating in 20 MHz bandwidth. Additionally, transmission using one to four spatial streams is defined for operation in 40 MHz bandwidth. These features are capable of supporting data rates up to 600 Mb/s (four spatial streams, 40 MHz bandwidth). Source: IEEE Standard 802.11n-2009 at 247. IEEE Standard 802.11n-2009 includes references to clause 17, which is not included in the text of IEEE 802.11n-2009 and refers to the last draft of IEEE 802.11-2007. That version includes mathematical conventions in the signal descriptions and the discrete-time implementations.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	17. Orthogonal frequency division multiplexing (OFDM) PHY specification for the 5 GHz band **17.1 Introduction** This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The half-clocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarter-clocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. Source: IEEE Standard 802.11-2007 at 591. **20.3.11.10 OFDM modulation**

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20.3.11.10.3 Transmission in 40 MHz HT format For 40 MHz HT transmissions, the signal from transmit chain i_{TX} shall be as shown in Equation (20-59). $$r_{HT-DATA}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-DATA}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} ([Q_k]_{i_{TX}, i_{STS}} (\tilde{D}_{k, i_{STS}, n} + p_{n+z} P_{(i_{STS}, n)}^{k}) \Upsilon_k \cdot \exp(j2\pi k \Delta_F (t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}}))) \quad (20\text{-}59)$$ 301

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	where z is 3 in an HT-mixed format packet and 2 in an HT-greenfield format packet p_n is defined in 17.3.5.9 $\tilde{D}_{k,\, i_{STS},\, n} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ \tilde{d}_{M^r(k),\, i_{STS},\, n}, \text{ otherwise} \end{cases}$ $M^r(k) = \begin{cases} k+58, -58 \le k \le -54 \\ k+57, -52 \le k \le -26 \\ k+56, -24 \le k \le -12 \\ k+55, -10 \le k \le -2 \\ k+52, 2 \le k \le 10 \\ k+51, 12 \le k \le 24 \\ k+50, 26 \le k \le 52 \\ k+49, 54 \le k \le 58 \end{cases}$ $P^k_{(i_{STS},\, n)}$ is defined in Equation (20-55) NOTE—The 90º rotation that is applied to the upper part of the 40 MHz channel is applied in the same way to the HT-STF, HT-LTF, and HT-SIG. The rotation applies to both pilots and the data in the upper part of the 40 MHz channel. Source: IEEE Standard 802.11n-2009 at 247, 298, 301-302. Section 20.3.7 describes that for the description of the convention on mathematical description of signals, see 17.3.2.4. That section refers back to a prior version of 802.11, which introduces 5 GHz OFDM PHY.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20.3.7 Mathematical description of signals For the description of the convention on mathematical description of signals, see 17.3.2.4. In the case of either a 20 MHz non-HT format (TXVECTOR parameter FORMAT set to NON_HT, MODULATION parameter set to one of {DSSS-OFDM, ERP-OFDM, OFDM}) transmission or a 20 MHz HT format (TXVECTOR parameter FORMAT set to HT_MF or HT_GF, CH_BANDWIDTH set to HT_CBW_20) transmission, the channel is divided into 64 subcarriers. In the 20 MHz non-HT format, the signal is transmitted on subcarriers –26 to –1 and 1 to 26, with 0 being the center (dc) carrier. In the 20 MHz HT format, the signal is transmitted on subcarriers –28 to –1 and 1 to 28. In the case of the 40 MHz HT format, a 40 MHz channel is used. The channel is divided into 128 subcarriers. The signal is transmitted on subcarriers –58 to –2 and 2 to 58. Source: IEEE Standard 802.11n-2009 at 267. The previous iteration of IEEE 802.11, IEEE 802.11-2007, includes Section 17.3.2.4.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	IEEE 802.11n™ IEEE Standard for Information technology— Telecommunications and information exchange between systems— Local and metropolitan area networks— Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 5: Enhancements for Higher Throughput IEEE Computer Society Sponsored by the LAN/MAN Standards Committee IEEE 3 Park Avenue New York, NY 10016-5997, USA 29 October 2009 IEEE Std 802.11n™-2009 (Amendment to IEEE Std 802.11™-2007 as amended by IEEE Std 802.11k™-2008, IEEE Std 802.11r™-2008, IEEE Std 802.11y™-2008, and IEEE Std 802.11w™-2009) Source: IEEE Standard 802.11n-2009 at 1. Section 17.3.2.4 includes a description of the use of OFDM, FFTs, and IFFTs.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)

Claim 1	Example Viasat Systems and Services
	(see below)

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \quad (17\text{-}1)$$

where

$Re(.)$ represents the real part of a complex variable

f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \quad (17\text{-}2)$$

The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \quad (17\text{-}3)$$

The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Source: IEEE Standard 802.11-2007 at 598.

On information and belief, IEEE 802.11ac infringes for the same reasons as 802.11n. *See supra*. *See also*:

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20. High Throughput (HT) PHY specification **20.1 Introduction** **20.1.1 Introduction to the HT PHY** ***Change the sixth paragraph of 20.1.1 as follows:*** An HT ~~non-AP~~ STA shall support all equal modulation (EQM) rates for one spatial stream (MCSs 0 to 7) using 20 MHz channel width. An HT AP that is not a VHT AP shall support all EQM rates for ~~one and~~ two spatial streams (MCSs ~~0~~ 8 to 15) using 20 MHz channel width. **20.3 HT PLCP sublayer** The HT PHY is based on the OFDM PHY defined in Clause 17, with extensibility up to four spatial streams, operating in 20 MHz bandwidth. Additionally, transmission using one to four spatial streams is defined for operation in 40 MHz bandwidth. These features are capable of supporting data rates up to 600 Mb/s (four spatial streams, 40 MHz bandwidth). Source: IEEE Standard 802.11ac-2013 at 213, which refers to 20.1.1 from the previous IEEE 802.11 draft which was IEEE 802.11-2012:

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20. High Throughput (HT) PHY specification **20.1 Introduction** **20.1.1 Introduction to the HT PHY** Clause 20 specifies the PHY entity for a high throughput (HT) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements found in Clause 20, an HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows: — In Clause 18 when the HT STA is operating in a 20 MHz channel width in the 5 GHz band — In Clause 17 and Clause 19 when the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band The HT PHY is based on the OFDM PHY defined in Clause 18, with extensibility up to four spatial streams, operating in 20 MHz bandwidth. Additionally, transmission using one to four spatial streams is defined for operation in 40 MHz bandwidth. These features are capable of supporting data rates up to 600 Mb/s (four spatial streams, 40 MHz bandwidth). Source: IEEE Standard 802.11-2012 at 1669. Section 22.3.7 includes a description of conventions used for mathematical description of signals, referring to Section 18.3.2.5. That section refers back to a prior version of 802.11.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.3.7 Mathematical description of signals **22.3.7.1 Notation** For a description of the conventions used for the mathematical description of the signals, see 18.3.2.5. In addition, the following notational conventions are used in Clause 22: $[Q]_{m,n}$ indicates the element in row m and column n of matrix Q, where $1 \le m \le N_{row}$ and $1 \le n \le N_{col}$ N_{row} and N_{col} are the number of rows and columns, respectively, of the matrix Q $[Q]_{M:N}$ indicates a matrix consisting of columns M to N of matrix Q Source: IEEE Standard 802.11ac-2013 at 247. The previous iteration of IEEE 802.11, IEEE 802.11-2012, includes section 18.3.2.5.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	IEEE Standard for Information technology— Telecommunications and information exchange between systems Local and metropolitan area networks— Specific requirements **Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications** **Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz** IEEE Computer Society Sponsored by the LAN/MAN Standards Committee IEEE 3 Park Avenue New York, NY 10016-5997 USA IEEE Std 802.11ac™-2013 (Amendment to IEEE Std 802.11™-2012, as amended by IEEE Std 802.11ae™-2012, IEEE Std 802.11aa™-2012, and IEEE Std 802.11ad™-2012) Source: IEEE Standard 802.11-2012 at 1. Section 18.3.2.5 describes the use of OFDM, FFTs, and IFFTs.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

18.3.2.5 Mathematical conventions in the signal descriptions

The transmitted signals are described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}\langle t\rangle = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\} \tag{18-1}$$

where

- $Re(.)$ represents the real part of a complex variable
- f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \tag{18-2}$$

The subframes of which Equation (18-2) are composed are described in 18.3.3, 18.3.4, and 18.3.5.10. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 18.3.3 to 18.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \tag{18-3}$$

The parameters Δ_F and N_{ST} are described in Table 18-5. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 18-5.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 18-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (18-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Source: IEEE Standard 802.11-2012 at 1591-1592.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.3.7.3 Channel frequencies Let $f_{c,\,\mathrm{idx0}}$ = dot11CurrentChannelCenterFrequencyIndex0 (22-1) $f_{c,\,\mathrm{idx1}}$ = dot11CurrentChannelCenterFrequencyIndex1 (22-2) $f_{\mathrm{P20,\,idx}}$ = dot11CurrentPrimaryChannel (22-3) $f_{\mathrm{CH,\,start}}$ = dot11ChannelStartingFactor × 500 kHz (22-4) where dot11CurrentChannelCenterFrequencyIndex0, dot11CurrentChannelCenterFrequencyIndex1, and dot11CurrentPrimaryChannel are defined in Table 22-22. When dot11CurrentChannelWidth (see Table 22-22) is 20 MHz, $f_{\mathrm{P20,\,idx}} = f_{c,\,\mathrm{idx0}}$. For dot11CurrentChannelWidth greater than 20 MHz, $f_{\mathrm{P20,\,idx}}$ and $f_{c,\,\mathrm{idx0}}$ shall have the relationship specified in Equation (22-5). $f_{\mathrm{P20,\,idx}} = f_{c,\,\mathrm{idx0}} - 4 \cdot \left(\frac{N_{\mathrm{20MHz}}}{2} - n_{\mathrm{P20}}\right) + 2$ (22-5) where $N_{\mathrm{20MHz}} = \begin{cases} 2, \text{ if dot11CurrentChannelWidth indicates 40 MHz} \\ 4, \text{ if dot11CurrentChannelWidth indicates 80 MHz and 80+80 MHz} \\ 8, \text{ if dot11CurrentChannelWidth indicates 160 MHz} \end{cases}$ Source: IEEE Standard 802.11ac-2013 at 248.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.3.7.4 Transmitted signal The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (22-11). $$r_{RF}^{(i_{Seg},\, i_{TX})}(t) = \mathrm{Re}\left\{\frac{1}{\sqrt{N_{Seg}}} r_{\mathrm{PPDU}}^{(i_{Seg},\, i_{TX})}(t)\exp(j2\pi f_c^{(i_{Seg})}t)\right\}, \quad (22\text{-}11)$$ $$i_{Seg} = 0, \ldots, N_{Seg}-1; \quad i_{TX} = 1, \ldots, N_{TX}$$ where $\mathrm{Re}\{.\}$ represents the real part of a complex variable; N_{Seg} represents the number of frequency segments in the transmit signal, as defined in Table 22-5; $r_{\mathrm{PPDU}}^{(i_{Seg},\, i_{TX})}(t)$ represents the complex baseband signal of frequency segment i_{Seg} in transmit chain i_{TX}; $f_c^{(i_{Seg})}$ represents the center frequency of the portion of the PPDU transmitted in frequency segment i_{Seg}. Table 22-7 shows $f_c^{(i_{Seg})}$ as a function of the channel starting frequency and dot11CurrentChannelWidth (see Table 22-22) where $f_{\mathrm{P20,\,idx}}$, $f_{\mathrm{P40,\,idx}}$, and $f_{\mathrm{P80,\,idx}}$ are given in Equation (22-4), Equation (22-5), Equation (22-7), and Equation (22-9), respectively. NOTE—Transmitted signals may have different impairments such as phase offset or phase noise between the two frequency segments, which is not shown in Equation (22-11) for simplicity. See 22.3.18.3. Source: IEEE Standard 802.11ac-2013 at 249. **19. High-throughput (HT) PHY specification** **19.3.11.11 OFDM modulation**

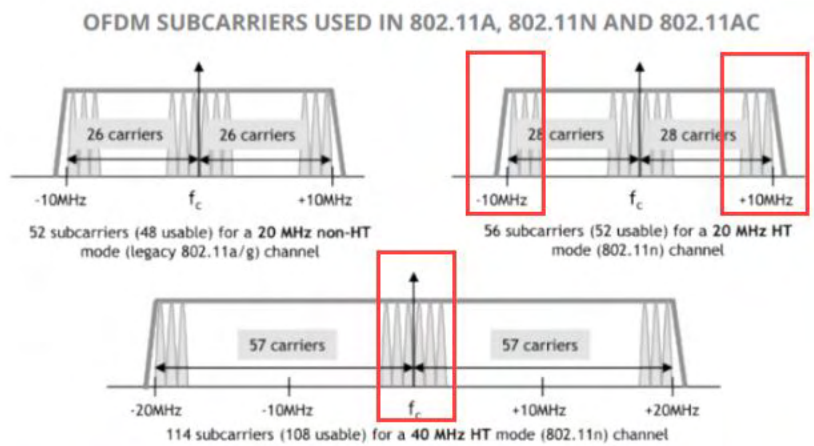
[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	19.3.11.11.4 Transmission in 40 MHz HT format For 40 MHz HT transmissions, the signal from transmit chain i_{TX} shall be as shown in Equation (19-59). $$r_{HT-DATA}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-DATA}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} ([Q_k]_{i_{TX}, i_{STS}}(\tilde{D}_{k, i_{STS}, n} + p_{n+z}P_{(i_{STS}, n)}^{k})\Upsilon_k \cdot \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})) \quad (19\text{-}59)$$ where z is 3 in an HT-mixed format packet and 2 in an HT-greenfield format packet p_n is defined in 17.3.5.10

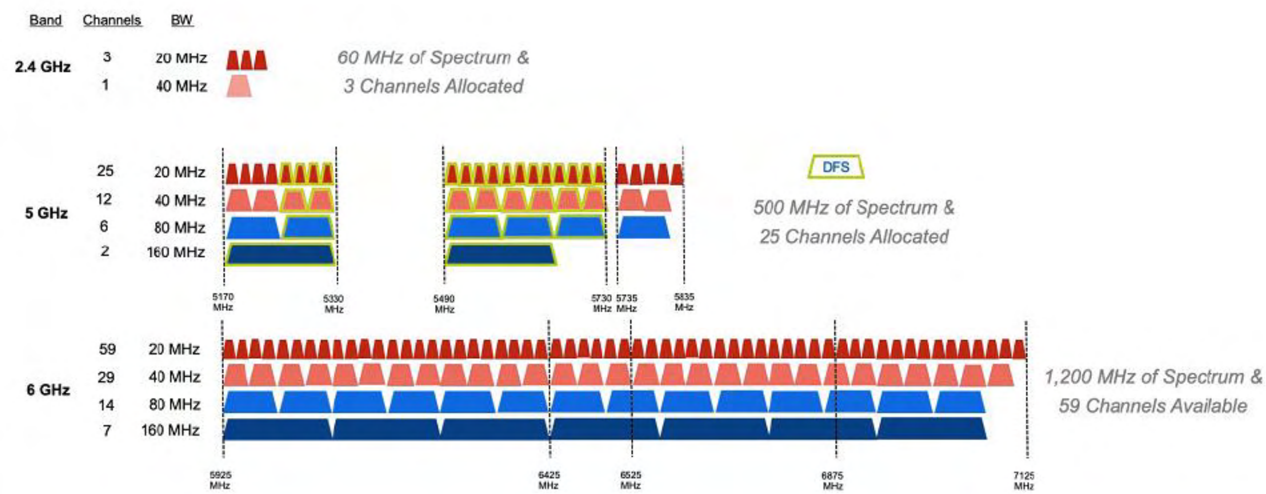
[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	$\tilde{D}_{k,i_{STS},n} = \begin{cases} 0, k = 0, \pm1, \pm11, \pm25, \pm53 \\ \tilde{d}_{M'(k),i_{STS},n}, \text{ otherwise} \end{cases}$ $M'(k) = \begin{cases} k+58, -58 \le k \le -54 \\ k+57, -52 \le k \le -26 \\ k+56, -24 \le k \le -12 \\ k+55, -10 \le k \le -2 \\ k+52, 2 \le k \le 10 \\ k+51, 12 \le k \le 24 \\ k+50, 26 \le k \le 52 \\ k+49, 54 \le k \le 58 \end{cases}$ $P^{k}_{(i_{STS},n)}$ is defined in Equation (19-55) NOTE—The 90° rotation that is applied to the upper part of the 40 MHz channel is applied in the same way to the HT-STF, HT-LTF, and HT-SIG. The rotation applies to both pilots and the data in the upper part of the 40 MHz channel. Source: IEEE Standard 802.11-2016 at 2334, 2387, 2390-2391.
[1.d] transmitting data subcarriers occupying the first channel, the second channel, and the frequency gap in parallel to a receiver.	On information and belief, the Viasat Systems and Services practice transmitting data subcarriers occupying the first channel, the second channel, and the frequency gap in parallel to a receiver. On information and belief, subcarriers occupying both channels and the partially filled frequency gap are transmitted in parallel.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	 Source: https://www.cablefree.net/wirelesstechnology/802-11ac/. Between the 2.4 GHz and 5 GHz spectrum available for Wi-Fi, there are 13 such 40 MHz channels that can occur:

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	 Source: https://www.everythingrf.com/community/what-frequency-band-does-wi-fi-6e-use. In each of these 13 cases, the two previous two 20-MHz channels that each had a 1 MHz guard band between these channels, now becomes one 40-MHz channel that can make use of those two 1 MHz guard bands between the two formerly 20-MHz channels:

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>

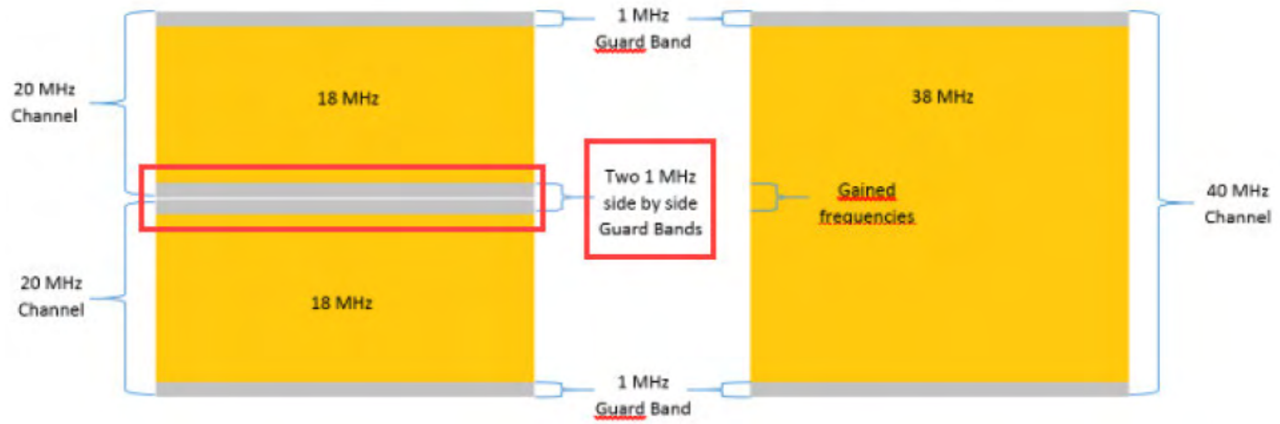


Figure 9: Gained frequencies from previous Gard Bands when using Channel Bonding

In fact, channel bounding more than doubles the throughput. One 20 MHz channel is composed of two 1 MHz channels, one at the beginning of the channel and one at the end, called Guard Bands. The 18 MHz left are used for data transfers. When using Channel Bonding, the two Guard Bands between two 20 MHz channels can now be used carry information.

Source:
https://www.gta.ufrj.br/ensino/eel879/trabalhos_vf_2014_2/remi/Physical%20Layer%20Improvements.html.

</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

	40MHZ OFDM 802.11N
	
	• 802.11n also introduced a 40 MHz channel, which combined two 20 MHz channels
	• The 40 MHz channel consists of 128 subcarriers:
	  • 128 subcarriers:
	    • 108 transmit data subcarriers
	    • 6 as pilot carriers
	    • 14 unused
	
	• When two 20 MHz HT channels are bonded together, some of the formerly unused subcarriers at the bottom of the higher channel and at the top end of the lower channel are able to be used to transmit data.
	• That is why the number of subcarriers is slightly more than two times the 56 subcarriers in a 20 MHz channel.
	• Each bonded channel consists of a primary and secondary 20 MHz channel.
	• The channels must be adjacent. A positive or negative offset indicates whether the secondary channel is the channel above or the channel below the primary channel. This is pictured in Figure 19.4.
	
	Source: https://dot11ap.wordpress.com/ht-channel-width-operation/.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Radio Enhancements

802.11n uses both 20-MHz and 40-MHz channels. Like the proprietary products, the 40-MHz channels in 802.11n are two adjacent 20-MHz channels, bonded together. When using the 40-MHz bonded channel,802.11n takes advantage of the fact that each 20-MHz channel has a small amount of the channel that is reserved at the top and bottom, to reduce interference in those adjacent channels. When using 40-MHz channels, the top of the lower channel and the bottom of the upper channel don't have to be reserved to avoid interference. These small parts of the channel can now be used to carry information. By using the two 20-MHz channels more efficiently in this way, 802.11n achieves slightly more than doubling the data rate when moving from 20-MHz to 40-MHz channels.

Source: https://vocal.com/networking/ieee-802-11n/.

Channel Bonding

Channel bonding is used in 802.11n to bind two 20 MHz channels, to make one 40 MHz channel. Doubling the frequency space doubles the bandwidth, and doubling the bandwidth doubles the throughput. We can make an analogy with a highway. Moving from a two lines highway to a four lines highway doubles the traffic capacity. Same result applies in network. While 802.11a and g used 20 MHz channels, 802.11n uses 40MHz channels, thanks to Channel Bonding (see the following figure).

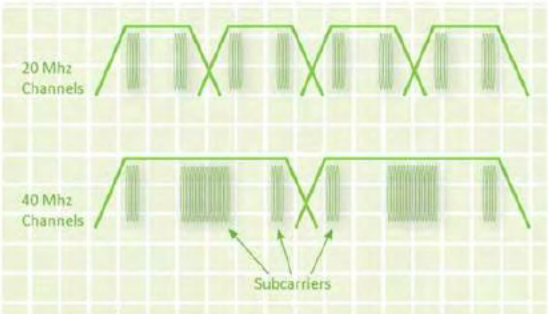


Figure 8: Channel Bonding

Source: https://www.gta.ufrj.br/ensino/eel879/trabalhos_vf_2014_2/remi/Physical%20Layer%20Improvements.html.

This is also described in IEEE 802.11n-2009:

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Grouping is a method that reduces the size of the CSI Report field by reporting a single value for each group of *Ng* adjacent subcarriers. With grouping, the size of the CSI Report field is $Nr\times 8+Ns\times(3+2\times Nb\times Nc\times Nr)$ bits, where the number of subcarriers sent, *Ns*, is a function of *Ng* and whether matrices for 40 MHz or 20 MHz are sent. The value of *Ns* and the specific carriers for which matrices are sent are shown in Table 7-25f. If the size of the CSI Report field is not an integral multiple of 8 bits, up to 7 zeros are appended to the end of the report to make its size an integral multiple of 8 bits. **Table 7-25f—Number of matrices and carrier grouping** (table below) Source: IEEE Standard 802.11n-2009 at 50. On information and belief, a 2 MHz frequency gap is present between the outer subcarriers of adjacent 20 MHz channels. In a 40 MHz bonded channel, this gap (6 sub carriers is partially filled with four additional subcarriers, corresponding to indexes –3,-2, +2 and +3. When two 20 MHz HT channels are bonded together, some of the formerly unused subcarriers at the bottom of the higher channel and at the top end of the lower channel can be used to transmit data, and the number of data subcarriers is slightly more than twice the number of subcarriers in a 40 MHz channel, as shown in table 19-6.

BW	Grouping *Ng*	*Ns*	Carriers for which matrices are sent
20 MHz	1	56	All data and pilot carriers: –28, –27,…–2, –1, 1, 2,…27, 28
	2	30	–28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–2,–1, 1,3,5,7,9,11,13,15,17,19,21,23,25,27,28
	4	16	–28,–24,–20,–16,–12,–8,–4,–1,1,5,9,13,17,21,25,28
40 MHz	1	114	All data and pilot carriers: –58, –57, …, –3, –2, 2, 3,…, 57, 58
	2	58	–58,–56,–54,–52,–50,–48,–46,–44,–42,–40,–38,–36,–34,–32,–30, –28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–2, 2,4,6,8,10,12,14,16,18,20,22,24,26,28, 30,32,34,36,38,40,42,44,46,48,50,52,54,56,58
	4	30	–58,–54,–50,–46,–42,–38,–34,–30,–26,–22,–18,–14,–10,–6, –2, 2,6,10,14,18,22,26,30,34,38,42,46,50,54,58

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Table 20-5—Timing-related constants

Parameter	TXVECTOR CH_BANDWIDTH			
	NON_HT_CBW20	HT_CBW_20	HT_CBW40 or NON_HT_CBW40	
			HT format	MCS 32 and non-HT duplicate
N_{SD}: Number of complex data numbers	48	52	108	48
N_{SP}: Number of pilot values	4	4	6	4
N_{ST}: Total number of subcarriers See NOTE 1	52	56	114	104

Source: IEEE Standard 802.11n-2009 at Table 20-5.

CH_BANDWIDTH	FORMAT is HT_MF or HT_GF	Indicates whether the packet is transmitted using 40 MHz or 20 MHz channel width. Enumerated type: HT_CBW20 for 20 MHz and 40 MHz upper and 40 MHz lower modes HT_CBW40 for 40 MHz	Y	Y
	FORMAT is NON_HT	Enumerated type: NON_HT_CBW40 for non-HT duplicate format NON_HT_CBW20 for all other non-HT formats	Y	Y

Source: IEEE Standard 802.11n-2009 at 251.

3. Definitions

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	3.242 primary channel: The common channel of operation for all stations (STAs) that are members of the basic service set (BSS). **3A.61 secondary channel:** A 20 MHz channel associated with a primary channel used by high-throughput (HT) stations (STAs) for the purpose of creating a 40 MHz channel. Source: IEEE Standard 802.11n-2009 at 2, 7.

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>

7.3.2.57 HT Operation element

The operation of HT STAs in the BSS is controlled by the HT Operation element. The structure of this element is defined in Figure 7-95o24.

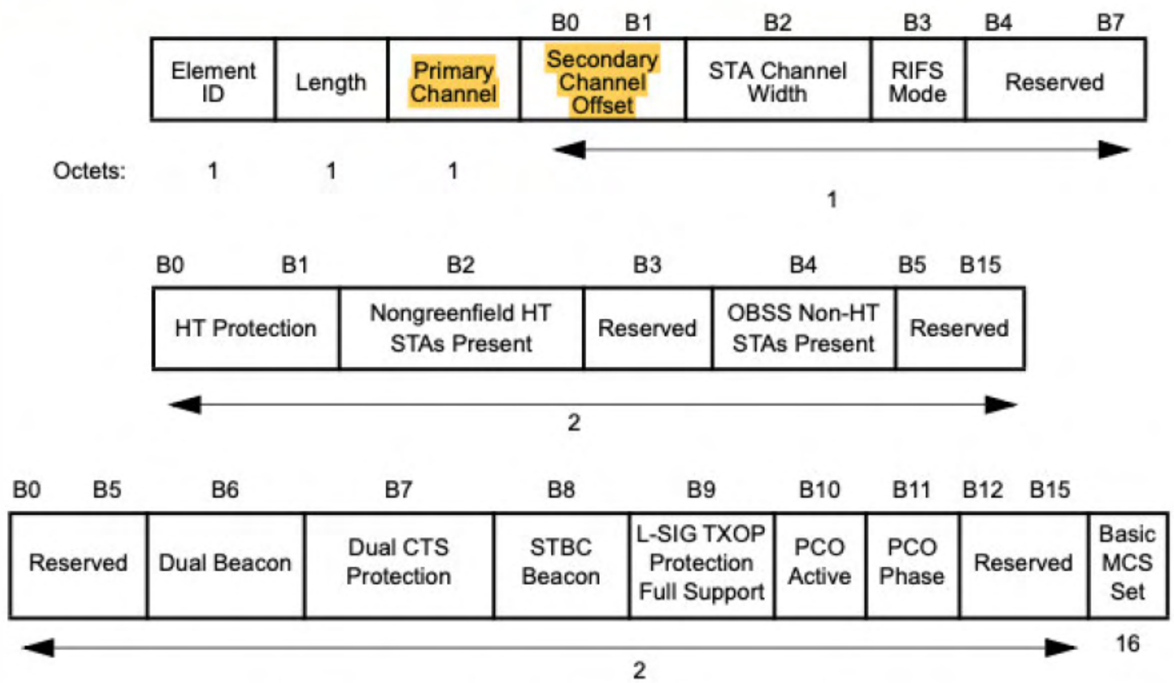


Figure 7-95o24—HT Operation element format

Source: IEEE Standard 802.11n-2009 at 76.

</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

The fields of the HT Operation element are defined in Table 7-43p. The "Reserved in IBSS?" column indicates whether each field is reserved (Y) or not reserved (N) when this element is present in a frame transmitted within an IBSS.

Table 7-43p—HT Operation element

Field	Definition	Encoding	Reserved in IBSS ?
Primary Channel	Indicates the channel number of the primary channel. See 11.14.2.	Channel number of the primary channel	N
Secondary Channel Offset	Indicates the offset of the secondary channel relative to the primary channel.	Set to 1 (SCA) if the secondary channel is above the primary channel Set to 3 (SCB) if the secondary channel is below the primary channel Set to 0 (SCN) if no secondary channel is present The value 2 is reserved	N

Source: IEEE Standard 802.11n-2009 at 77.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	(see Table 20-5 below)

Table 20-5—Timing-related constants

Parameter	TXVECTOR CH_BANDWIDTH			
	NON_HT_CBW20	HT_CBW_20	HT_CBW40 or NON_HT_CBW40	
			HT format	MCS 32 and non-HT duplicate
N_{SD}: Number of complex data numbers	48	52	108	48
N_{SP}: Number of pilot values	4	4	6	4
N_{ST}: Total number of subcarriers See NOTE 1	52	56	114	104

Source: IEEE Standard 802.11n-2009 at Table 20-5.

[redacted]

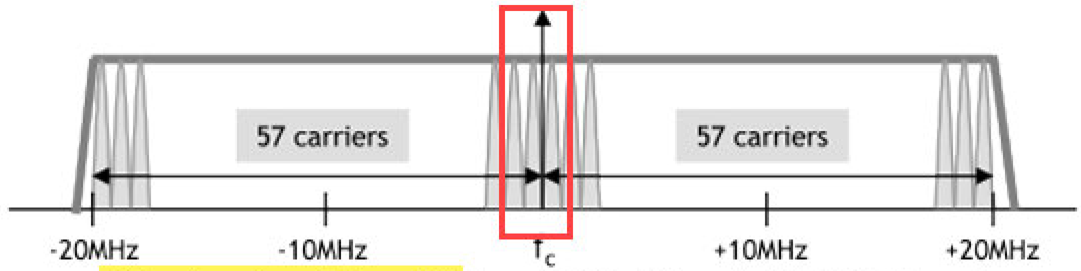
U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	20.3.11.10.3 Transmission in 40 MHz HT format For 40 MHz HT transmissions, the signal from transmit chain i_{TX} shall be as shown in Equation (20-59). $r_{HT-DATA}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-DATA}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM})$ $\cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} ([Q_k]_{i_{TX}, i_{STS}} (\tilde{D}_{k, i_{STS}, n} + p_{n+z} P_{(i_{STS}, n)}^{k}) \Upsilon_k$ (20-59) $\cdot \exp(j2\pi k \Delta_F (t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})))$ 301

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	where z is 3 in an HT-mixed format packet and 2 in an HT-greenfield format packet p_n is defined in 17.3.5.9 $$\tilde{D}_{k,\, i_{STS},\, n} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ \tilde{d}_{M^r(k),\, i_{STS},\, n}, \text{ otherwise} \end{cases}$$ $$M^r(k) = \begin{cases} k+58, -58 \le k \le -54 \\ k+57, -52 \le k \le -26 \\ k+56, -24 \le k \le -12 \\ k+55, -10 \le k \le -2 \\ k+52, 2 \le k \le 10 \\ k+51, 12 \le k \le 24 \\ k+50, 26 \le k \le 52 \\ k+49, 54 \le k \le 58 \end{cases}$$ $P^k_{(i_{STS},\, n)}$ is defined in Equation (20-55) NOTE—The 90º rotation that is applied to the upper part of the 40 MHz channel is applied in the same way to the HT-STF, HT-LTF, and HT-SIG. The rotation applies to both pilots and the data in the upper part of the 40 MHz channel. Source: IEEE Standard 802.11n-2009 at 301-302.

[redacted]

On information and belief, IEEE 802.11ac infringes for the same reasons as 802.11n. *See supra*. *See also*:



114 subcarriers (108 usable) for a **40 MHz HT** mode (802.11n) channel

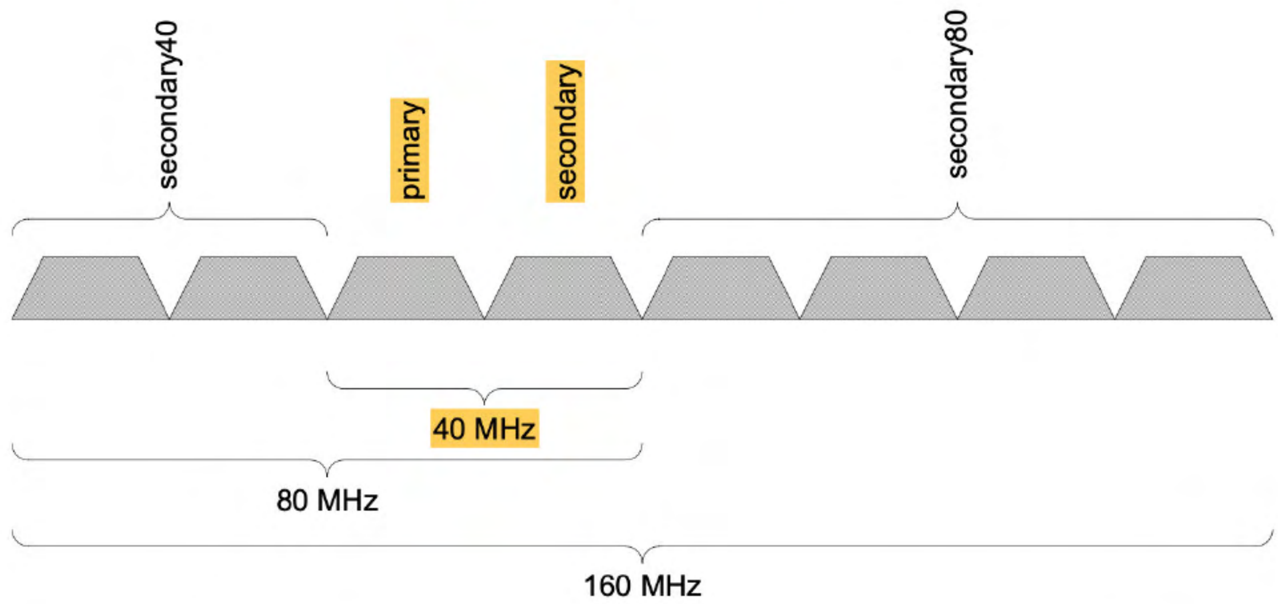
Source: https://www.arubanetworks.com/assets/wp/WP_80211acInDepth.pdf.

3.2 Definitions specific to IEEE 802.11

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	primary 20 MHz channel: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel that is used to transmit 20 MHz physical layer (PHY) protocol data units (PPDUs). In a VHT BSS, the primary 20 MHz channel is also the primary channel. **primary 40 MHz channel:** In an 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 40 MHz channel that is used to transmit 40 MHz physical layer (PHY) protocol data units (PPDUs). **primary 80 MHz channel:** In a 160 MHz or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 80 MHz channel that is used to transmit 80 MHz physical layer (PHY) protocol data units (PPDUs). **primary access category (AC):** The access category (AC) associated with the enhanced distributed channel access function (EDCAF) that gains channel access. **secondary 20 MHz channel**: In a 40 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel adjacent to the primary 20 MHz channel that together form the 40 MHz channel of the 40 MHz VHT BSS. In an 80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 80 MHz VHT BSS. In a 160 MHz or 80+80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 160 MHz or 80+80 MHz VHT BSS. In a VHT BSS, the secondary 20 MHz channel is also the secondary channel. **secondary channel**: A 20 MHz channel associated with a primary channel used by high-throughput (HT) stations (STAs) for the purpose of creating a 40 MHz channel or used by very high throughput (VHT) stations (STAs) for the purpose of creating the primary 40 MHz channel. **non-primary channel**: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), any 20 MHz channel other than the primary 20 MHz channel. Source: IEEE Standard 802.11ac-2013 at 2, 4, 7.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	 **Figure 7-1—The channel-list parameter element for 40 MHz, 80 MHz, and 160 MHz channel width** Source: IEEE Standard 802.11ac-2013 at 31.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	4.3.10a Very high throughput (VHT) STA This subclause summarizes the normative requirements for an IEEE 802.11 VHT STA stated elsewhere in this standard. The IEEE 802.11 VHT STA operates in frequency bands below 6 GHz excluding the 2.4 GHz band. A VHT STA is an HT STA that, in addition to features supported as an HT STA, supports VHT features identified in Clause 8, Clause 9, Clause 10, Clause 13, Clause 18, and Clause 22. The main PHY features in a VHT STA that are not present in an HT STA are the following: — Mandatory support for 40 MHz and 80 MHz channel widths — Mandatory support for VHT single-user (SU) PPDUs — Optional support for 160 MHz and 80+80 MHz channel widths — Optional support for VHT sounding protocol to support beamforming — Optional support for VHT multi-user (MU) PPDUs — Optional support for VHT-MCSs 8 and 9 Source: IEEE Standard 802.11ac-2013 at 10.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.5 Parameters for VHT-MCSs The rate-dependent parameters for 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz $N_{SS} = 1, \ldots, 8$ are given in Table 22-30 through Table 22-61. Support for 400 ns GI is optional in all cases. Support for VHT-MCS 8 and 9 (when valid) is optional in all cases. A VHT STA shall support single spatial stream VHT-MCSs within the range VHT-MCS 0 to VHT-MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported VHT-MCS and NSS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported VHT-MCS and NSS Set field may result in a reduced VHT-MCS range (cut-off) for $N_{SS} = 2, \ldots, 8$. Support for 20 MHz, 40 MHz, and 80 MHz with $N_{SS} = 1$ is mandatory. Support for 20 MHz, 40 MHz, and 80 MHz with $N_{SS} = 2, \ldots, 8$ is optional. Support for 160 MHz and 80+80 MHz with $N_{SS} = 1, \ldots, 8$ is optional. N_{ES} values were chosen to yield an integer number of punctured blocks for each BCC encoder per OFDM symbol. Table 22-30 to Table 22-33, Table 22-38 to Table 22-41, Table 22-46 to Table 22-49, and Table 22-54 to Table 22-57 define VHT-MCSs not only for SU transmission but also for user u of MU transmission. In the case of VHT-MCSs for MU transmission, the parameters, N_{SS}, R, N_{BPSCS}, N_{CBPS}, N_{DBPS}, and N_{ES} are replaced with $N_{SS,u}$, R_u, $N_{BPSCS,u}$, $N_{CBPS,u}$, $N_{DBPS,u}$, and $N_{ES,u}$, respectively. Source: IEEE Standard 802.11ac-2013 at 323.

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U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Table 22-38—VHT-MCSs for mandatory 40 MHz, N_{SS} = 1 (see table below) Source: IEEE Standard 802.11ac-2013 at 328.

VHT-MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	108	54	1	13.5	15.0
1	QPSK	1/2	2	108	6	216	108	1	27.0	30.0
2	QPSK	3/4	2	108	6	216	162	1	40.5	45.0
3	16-QAM	1/2	4	108	6	432	216	1	54.0	60.0
4	16-QAM	3/4	4	108	6	432	324	1	81.0	90.0
5	64-QAM	2/3	6	108	6	648	432	1	108.0	120.0
6	64-QAM	3/4	6	108	6	648	486	1	121.5	135.0
7	64-QAM	5/6	6	108	6	648	540	1	135.0	150.0
8	256-QAM	3/4	8	108	6	864	648	1	162.0	180.0
9	256-QAM	5/6	8	108	6	864	720	1	180.0	200.0

Source: IEEE Standard 802.11ac-2013 at 328.

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U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Table 22-5—Timing-related constants

Parameter	CBW20	CBW40	CBW80	CBW80+80	CBW160	Description
N_{SD}	52	108	234	234	468	Number of complex data numbers per frequency segment
N_{SP}	4	6	8	8	16	Number of pilot values per frequency segment
N_{ST}	56	114	242	242	484	Total number of subcarriers per frequency segment. See NOTE.
N_{SR}	28	58	122	122	250	Highest data subcarrier index per frequency segment
N_{Seg}	1	1	1	2	1	Number of frequency segments
Δ_F	312.5 kHz					Subcarrier frequency spacing
T_{DFT}	3.2 µs					IDFT/DFT period

Source: IEEE Standard 802.11ac-2013 at Table 20-5.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.3.7.3 Channel frequencies Let $f_{c,\ \mathrm{idx0}} = \mathrm{dot11CurrentChannelCenterFrequencyIndex0}$ (22-1) $f_{c,\ \mathrm{idx1}} = \mathrm{dot11CurrentChannelCenterFrequencyIndex1}$ (22-2) $f_{\mathrm{P20,\ idx}} = \mathrm{dot11CurrentPrimaryChannel}$ (22-3) $f_{\mathrm{CH,\ start}} = \mathrm{dot11ChannelStartingFactor} \times 500\ \mathrm{kHz}$ (22-4) where dot11CurrentChannelCenterFrequencyIndex0, dot11CurrentChannelCenterFrequencyIndex1, and dot11CurrentPrimaryChannel are defined in Table 22-22. When dot11CurrentChannelWidth (see Table 22-22) is 20 MHz, $f_{\mathrm{P20,\ idx}} = f_{c,\ \mathrm{idx0}}$. For dot11CurrentChannelWidth greater than 20 MHz, $f_{\mathrm{P20,\ idx}}$ and $f_{c,\ \mathrm{idx0}}$ shall have the relationship specified in Equation (22-5). $f_{\mathrm{P20,\ idx}} = f_{c,\ \mathrm{idx0}} - 4 \cdot \left(\frac{N_{\mathrm{20MHz}}}{2} - n_{\mathrm{P20}}\right) + 2$ (22-5) where $N_{\mathrm{20MHz}} = \begin{cases} 2\text{, if dot11CurrentChannelWidth indicates 40 MHz} \\ 4\text{, if dot11CurrentChannelWidth indicates 80 MHz and 80+80 MHz} \\ 8\text{, if dot11CurrentChannelWidth indicates 160 MHz} \end{cases}$ Source: IEEE Standard 802.11ac-2013 at 248.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	22.3.7.4 Transmitted signal The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (22-11). $r_{RF}^{(i_{Seg}, i_{TX})}(t) = \mathrm{Re}\left\{ \frac{1}{\sqrt{N_{Seg}}} r_{\mathrm{PPDU}}^{(i_{Seg}, i_{TX})}(t) \exp(j 2\pi f_c^{(i_{Seg})} t) \right\},$ (22-11) $i_{Seg} = 0, \ldots, N_{Seg} - 1; \quad i_{TX} = 1, \ldots, N_{TX}$ where $\mathrm{Re}\{.\}$ represents the real part of a complex variable; N_{Seg} represents the number of frequency segments in the transmit signal, as defined in Table 22-5; $r_{\mathrm{PPDU}}^{(i_{Seg}, i_{TX})}(t)$ represents the complex baseband signal of frequency segment i_{Seg} in transmit chain i_{TX}; $f_c^{(i_{Seg})}$ represents the center frequency of the portion of the PPDU transmitted in frequency segment i_{Seg}. Table 22-7 shows $f_c^{(i_{Seg})}$ as a function of the channel starting frequency and dot11CurrentChannelWidth (see Table 22-22) where $f_{\mathrm{P20, idx}}$, $f_{\mathrm{P40, idx}}$, and $f_{\mathrm{P80, idx}}$ are given in Equation (22-4), Equation (22-5), Equation (22-7), and Equation (22-9), respectively. NOTE—Transmitted signals may have different impairments such as phase offset or phase noise between the two frequency segments, which is not shown in Equation (22-11) for simplicity. See 22.3.18.3. Source: IEEE Standard 802.11ac-2013 at 249.

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U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**

Table 8-53g—Subcarriers for which a Compressed Beamforming Feedback Matrix subfield is sent back

Channel Width	*Ng*	*Ns*	Subcarriers for which Compressed Feedback Beamforming Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1)
20 MHz	1	52	–28, –27, –26, –25, –24, –23, –22, –20, –19, –18, –17, –16, –15, –14, –13, –12, –11, –10, –9, –8, –6, –5, –4, –3, –2, –1, 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28 NOTE—Pilot subcarriers (±21, ±7) and DC subcarrier (0) are skipped
	2	30	–28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28
	4	16	–28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28
40 MHz	1	108	–58, –57, –56, –55, –54, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58 NOTE—Pilot subcarriers (±53, ±25, ±11) and DC subcarriers (0, ±1) are skipped.
	2	58	–58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, -22, –20, –18, –16, –14, –12, –10, –8, –6, –4,–2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58
	4	30	–58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6,–2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58

Source: IEEE Standard 802.11ac-2013 at 59.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Table 8-53j—Number of subcarriers and subcarrier mapping

Channel Width	*Ng*	*Ns′*	Subcarriers for which the Delta SNR subfield is sent: *sscidx*(0), *sscidx*(1), … *sscidx*(*Ns′*–1)
20 MHz	1	30	–28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28
	2	16	–28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28
	4	10	–28, –20, –12, –4, –1, 1, 4, 12, 20, 28
40 MHz	1	58	–58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4,–2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58
	2	30	–58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6,–2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58
	4	16	–58, –50, –42, –34, –26, –18, –10, –2, 2, 10, 18, 26, 34, 42, 50, 58

Source: IEEE Standard 802.11ac-2013 at 66.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	Table 10-19—VHT BSS operating channel width | HT Operation element STA Channel Width field | VHT Operation element Channel Width field | BSS operating channel width | |---|---|---| | 0 | 0 | 20 MHz | | 1 | 0 | 40 MHz | | 1 | 1 | 80 MHz | | 1 | 2 | 160 MHz | | 1 | 3 | 80+80 MHz | Source: IEEE Standard 802.11ac-2013 at 186. **20.3.4 Overview of the PPDU encoding process**

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	o) Determine whether 20 MHz or 40 MHz operation is to be used from the CH_BANDWIDTH parameter of the TXVECTOR. Specifically, when CH_BANDWIDTH is HT_CBW20 or NON_HT_CBW20, 20 MHz operation is to be used. When CH_BANDWIDTH is HT_CBW40 or NON_HT_CBW40, 40 MHz operation is to be used. For 20 MHz operation (with the exception of non-HT formats), insert four subcarriers as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers, N_{ST}, is 56. For 40 MHz operation (with the exception of MCS 32 and non-HT duplicate format), insert six subcarriers as pilots into positions –53, –25, –11, 11, 25, and 53, resulting in a total of N_{ST} = 114 subcarriers. See 20.3.11.10.4 for pilot locations when using MCS 32 and 20.3.11.11 for pilot locations when using non-HT duplicate format. The pilots are modulated using a pseudo-random cover sequence. Refer to 20.3.11.9 for details. For 40 MHz operation, apply a +90 degree phase shift to the complex value in each OFDM subcarrier with an index greater than 0, as described in 20.3.11.10.3, 20.3.11.10.4, and 20.3.11.11. p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation, $N_{TX} = N_{STS}$, and there is a one-to-one correspondence between space-time streams and transmit chains. In this case, the OFDM symbols associated with each space-time stream are also associated with the corresponding transmit chain. Otherwise, a spatial mapping matrix associated with each OFDM subcarrier, as indicated by the EXPANSION_MAT parameter of the TXVECTOR, is used to perform a linear transformation on the vector of N_{STS} complex numbers associated with each subcarrier in each OFDM symbol. This spatial mapping matrix maps the vector of N_{STS} complex numbers in each subcarrier into a vector of N_{TX} complex numbers in each subcarrier. The sequence of N_{ST} complex numbers associated with each transmit chain (where each of the N_{ST} complex numbers is taken from the same position in the N_{TX} vector of complex numbers across the N_{ST} subcarriers associated with an OFDM symbol) constitutes an OFDM symbol associated with the corresponding transmit chain. For details, see 20.3.11.10. Spatial mapping matrices may include cyclic shifts, as described in 20.3.11.10.1.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	t) Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 20.3.7 for details. The transmit chains are connected to antenna elements according to ANTENNA_SET of the TXVECTOR if ASEL is applied. Source: IEEE Standard 802.11n-2009 at 262-264. On information and belief, IEEE 802.11ac infringes for the same reasons as 802.11n. *See supra*. *See also*: **20.3.4 Overview of the PPDU encoding process** The encoding process is composed of the steps described below. The following overview is intended to facilitate an understanding of the details of the convergence procedure:

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	o) Determine whether 20 MHz or 40 MHz operation is to be used from the CH_BANDWIDTH parameter of the TXVECTOR. Specifically, when CH_BANDWIDTH is HT_CBW20 or NON_HT_CBW20, 20 MHz operation is to be used. When CH_BANDWIDTH is HT_CBW40 or NON_HT_CBW40, 40 MHz operation is to be used. For 20 MHz operation (with the exception of non-HT formats), insert four subcarriers as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers, N_{ST}, is 56. For 40 MHz operation (with the exception of MCS 32 and non-HT duplicate format), insert six subcarriers as pilots into positions –53, –25, –11, 11, 25, and 53, resulting in a total of $N_{ST} = 114$ subcarriers. See 20.3.11.11.5 for pilot locations when using MCS 32 and 20.3.11.12 for pilot locations when using non-HT duplicate format. The pilots are modulated using a pseudorandom cover sequence. Refer to 20.3.11.10 for details. For 40 MHz operation, apply a +90 degree phase shift to the complex value in each OFDM subcarrier with an index greater than 0, as described in 20.3.11.11.4, 20.3.11.11.5, and 20.3.11.12. p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation, $N_{TX} = N_{STS}$, and there is a one-to-one correspondence between space-time streams and transmit chains. In this case, the OFDM symbols associated with each space-time stream are also associated with the corresponding transmit chain. Otherwise, a spatial mapping matrix associated with each OFDM subcarrier, as indicated by the EXPANSION_MAT parameter of the TXVECTOR, is used to perform a linear transformation on the vector of N_{STS} complex numbers associated with each subcarrier in each OFDM symbol. This spatial mapping matrix maps the vector of N_{STS} complex numbers in each subcarrier into a vector of N_{TX} complex numbers in each subcarrier. The sequence of N_{ST} complex numbers associated with each transmit chain (where each of the N_{ST} complex numbers is taken from the same position in the N_{TX} vector of complex numbers across the N_{ST} subcarriers associated with an OFDM symbol) constitutes an OFDM symbol associated with the corresponding transmit chain. For details, see 20.3.11.11. Spatial mapping matrices may include cyclic shifts, as described in 20.3.11.11.2.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	t) Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 20.3.7 for details. The transmit chains are connected to antenna elements according to ANTENNA_SET of the TXVECTOR if ASEL is applied. Source: IEEE Standard 802.11-2012 at 1684-1688. **19.3.4 Overview of the PPDU encoding process**

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	o) Determine whether 20 MHz or 40 MHz operation is to be used from the CH_BANDWIDTH parameter of the TXVECTOR. Specifically, when CH_BANDWIDTH is HT_CBW20 or NON_HT_CBW20, 20 MHz operation is to be used. When CH_BANDWIDTH is HT_CBW40 or NON_HT_CBW40, 40 MHz operation is to be used. For 20 MHz operation (with the exception of non-HT formats), insert four subcarriers as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers, N_{ST}, is 56. For 40 MHz operation (with the exception of MCS 32 and non-HT duplicate format), insert six subcarriers as pilots into positions –53, –25, –11, 11, 25, and 53, resulting in a total of N_{ST} = 114 subcarriers. See 19.3.11.11.5 for pilot locations when using MCS 32 and 19.3.11.12 for pilot locations when using non-HT duplicate format. The pilots are modulated using a pseudorandom cover sequence. Refer to 19.3.11.10 for details. For 40 MHz operation, apply a +90° phase shift to the complex value in each OFDM subcarrier with an index greater than 0, as described in 19.3.11.11.4, 19.3.11.11.5, and 19.3.11.12. p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation, $N_{TX} = N_{STS}$, and there is a one-to-one correspondence between space-time streams and transmit chains. In this case, the OFDM symbols associated with each space-time stream are also associated with the corresponding transmit chain. Otherwise, a spatial mapping matrix associated with each OFDM subcarrier, as indicated by the EXPANSION_MAT parameter of the TXVECTOR, is used to perform a linear transformation on the vector of N_{STS} complex numbers associated with each subcarrier in each OFDM symbol. This spatial mapping matrix maps the vector of N_{STS} complex numbers in each subcarrier into a vector of N_{TX} complex numbers in each subcarrier. The sequence of N_{ST} complex numbers associated with each transmit chain (where each of the N_{ST} complex numbers is taken from the same position in the N_{TX} vector of complex numbers across the N_{ST} subcarriers associated with an OFDM symbol) constitutes an OFDM symbol associated with the corresponding transmit chain. For details, see 19.3.11.11. Spatial mapping matrices may include cyclic shifts, as described in 19.3.11.11.2.

[redacted]

U.S. Patent No. 8,027,326 (Claim 1)	
Claim 1	**Example Viasat Systems and Services**
	t) Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 19.3.7 for details. The transmit chains are connected to antenna elements according to ANTENNA_SET of the TXVECTOR if ASEL is applied. Source: IEEE Standard 802.11-2016 at 2349-2353.

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
[4] The method of claim 1, wherein transmitting the first channel and the second channel comprises transmitting to multiple radios.	On information and belief, the Viasat Systems and Services practice the method of claim 1. *See* claim 1. On information and belief, the Viasat Systems and Services further practice the transmitting the first channel and the second channel includes transmitting to multiple radios. On information and belief, subcarriers occupying both channels and the partially filled frequency gap are transmitted in parallel and can be transmitted to multiple radios. **802.11n** In January, 2004 the IEEE 802.11 task group initiated work. The standard was finally ratified in September 2009. The goal of 802.11n is to significantly increase the data throughput rate. While there are a number of technical changes, one important change is the addition of multiple-input multiple-output (MIMO) and spatial multiplexing. Multiple antennas are used in MIMO, which use multiple radios and therefore utilizes more electrical power. Source: https://www.air802.com/ieee-802.11-standards-facts-amp-channels.html. Starting from Section 20.3.4 in IEEE 802.11n-2009, where the 40 MHz operation is described, there are subsequent subsections that describe transmitting to multiple radios.

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	20.3.4 Overview of the PPDU encoding process o) Determine whether 20 MHz or 40 MHz operation is to be used from the CH_BANDWIDTH parameter of the TXVECTOR. Specifically, when CH_BANDWIDTH is HT_CBW20 or NON_HT_CBW20, 20 MHz operation is to be used. When CH_BANDWIDTH is HT_CBW40 or NON_HT_CBW40, 40 MHz operation is to be used. For 20 MHz operation (with the exception of non-HT formats), insert four subcarriers as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers, N_{ST}, is 56. For 40 MHz operation (with the exception of MCS 32 and non-HT duplicate format), insert six subcarriers as pilots into positions –53, –25, –11, 11, 25, and 53, resulting in a total of N_{ST} = 114 subcarriers. See 20.3.11.10.4 for pilot locations when using MCS 32 and 20.3.11.11 for pilot locations when using non-HT duplicate format. The pilots are modulated using a pseudo-random cover sequence. Refer to 20.3.11.9 for details. For 40 MHz operation, apply a +90 degree phase shift to the complex value in each OFDM subcarrier with an index greater than 0, as described in 20.3.11.10.3, 20.3.11.10.4, and 20.3.11.11. p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation, $N_{TX} = N_{STS}$, and there is a one-to-one correspondence between space-time streams and transmit chains. In this case, the OFDM symbols associated with each space-time stream are also associated with the corresponding transmit chain. Otherwise, a spatial mapping matrix associated with each OFDM subcarrier, as indicated by the EXPANSION_MAT parameter of the TXVECTOR, is used to perform a linear transformation on the vector of N_{STS} complex numbers associated with each subcarrier in each OFDM symbol. This spatial mapping matrix maps the vector of N_{STS} complex numbers in each subcarrier into a vector of N_{TX} complex numbers in each subcarrier. The sequence of N_{ST} complex numbers associated with each transmit chain (where each of the N_{ST} complex numbers is taken from the same position in the N_{TX} vector of complex numbers across the N_{ST} subcarriers associated with an OFDM symbol) constitutes an OFDM symbol associated with the corresponding transmit chain. For details, see 20.3.11.10. Spatial mapping matrices may include cyclic shifts, as described in 20.3.11.10.1.

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	t) Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 20.3.7 for details. The transmit chains are connected to antenna elements according to ANTENNA_SET of the TXVECTOR if ASEL is applied. Source: IEEE Standard 802.11n-2009 at 262-264. As another example, Section 20.3.12 describes using a 3x2 example, meaning 3 radios on the transmit side and 2 radios on the receive side. **20.3.12 Beamforming** Beamforming is a technique in which the beamformer utilizes the knowledge of the MIMO channel to generate a steering matrix Q_k that improves reception in the beamformee. The equivalent complex baseband MIMO channel model is one in which, when a vector $\mathbf{x}_k = [x_1, x_2, \ldots x_{N_{TX}}]^T$ is transmitted in subcarrier k, the received vector $\mathbf{y}_k = [y_1, y_2, \ldots y_{N_{RX}}]^T$ is modeled as shown in Equation (20-62).

[redacted]

$$\mathbf{y}_k = H_k \mathbf{x}_k + \mathbf{n} \tag{20-62}$$

where

H_k is channel matrix of dimensions $N_{RX} \times N_{TX}$

$\mathbf{n}$ is white (spatially and temporally) Gaussian noise as illustrated in Figure 20-14

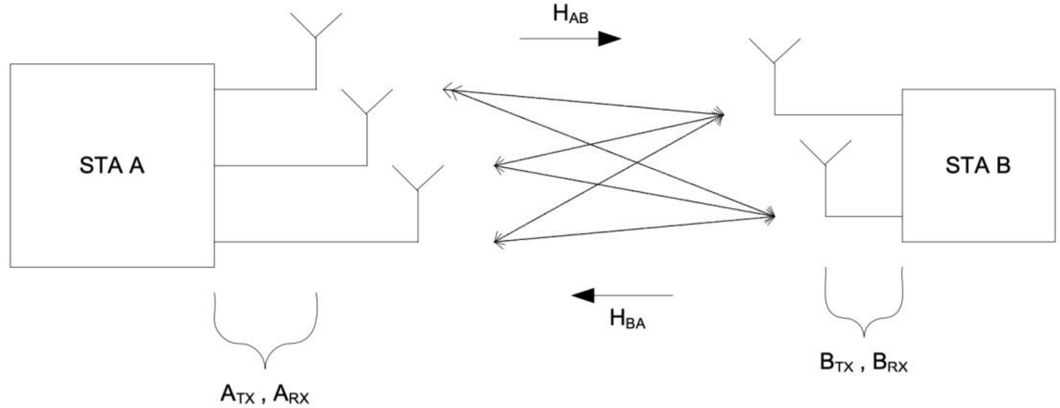


Figure 20-14—Beamforming MIMO channel model (3x2 example)

When beamforming is used, the beamformer replaces $\mathbf{x}_k$, which in this case has $N_{STS} \le N_{TX}$ elements, with $Q_k \mathbf{x}_k$, where Q_k has N_{TX} rows and N_{STS} columns, so that the received vector is as shown in Equation (20-63).

$$\mathbf{y}_k = H_k Q_k \mathbf{x}_k + \mathbf{n} \tag{20-63}$$

The beamforming steering matrix that is computed (or updated) from a new channel measurement replaces the existing Q_k for the next beamformed data transmission. There are several methods of beamforming, differing in the way the beamformer acquires the knowledge of the channel matrices H_k and on whether the beamformer generates Q_k or the beamformee provides feedback information for the beamformer to generate Q_k.

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	Source: IEEE 802.11n-2009 pages 303-304. On information and belief, IEEE 802.11ac infringes for the same reasons as 802.11n. *See supra*. *See also*: **20.3.4 Overview of the PPDU encoding process** The encoding process is composed of the steps described below. The following overview is intended to facilitate an understanding of the details of the convergence procedure:

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	o) Determine whether 20 MHz or 40 MHz operation is to be used from the CH_BANDWIDTH parameter of the TXVECTOR. Specifically, when CH_BANDWIDTH is HT_CBW20 or NON_HT_CBW20, 20 MHz operation is to be used. When CH_BANDWIDTH is HT_CBW40 or NON_HT_CBW40, 40 MHz operation is to be used. For 20 MHz operation (with the exception of non-HT formats), insert four subcarriers as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers, N_{ST}, is 56. For 40 MHz operation (with the exception of MCS 32 and non-HT duplicate format), insert six subcarriers as pilots into positions –53, –25, –11, 11, 25, and 53, resulting in a total of N_{ST} = 114 subcarriers. See 20.3.11.11.5 for pilot locations when using MCS 32 and 20.3.11.12 for pilot locations when using non-HT duplicate format. The pilots are modulated using a pseudorandom cover sequence. Refer to 20.3.11.10 for details. For 40 MHz operation, apply a +90 degree phase shift to the complex value in each OFDM subcarrier with an index greater than 0, as described in 20.3.11.11.4, 20.3.11.11.5, and 20.3.11.12. p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation, $N_{TX} = N_{STS}$, and there is a one-to-one correspondence between space-time streams and transmit chains. In this case, the OFDM symbols associated with each space-time stream are also associated with the corresponding transmit chain. Otherwise, a spatial mapping matrix associated with each OFDM subcarrier, as indicated by the EXPANSION_MAT parameter of the TXVECTOR, is used to perform a linear transformation on the vector of N_{STS} complex numbers associated with each subcarrier in each OFDM symbol. This spatial mapping matrix maps the vector of N_{STS} complex numbers in each subcarrier into a vector of N_{TX} complex numbers in each subcarrier. The sequence of N_{ST} complex numbers associated with each transmit chain (where each of the N_{ST} complex numbers is taken from the same position in the N_{TX} vector of complex numbers across the N_{ST} subcarriers associated with an OFDM symbol) constitutes an OFDM symbol associated with the corresponding transmit chain. For details, see 20.3.11.11. Spatial mapping matrices may include cyclic shifts, as described in 20.3.11.11.2.

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	t) Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 20.3.7 for details. The transmit chains are connected to antenna elements according to ANTENNA_SET of the TXVECTOR if ASEL is applied. Source: IEEE Standard 802.11-2012 at 1684-1688.

[redacted]

20.3.12 Beamforming

20.3.12.1 General

Beamforming is a technique in which the beamformer utilizes the knowledge of the MIMO channel to generate a steering matrix Q_k that improves reception in the beamformee.

The equivalent complex baseband MIMO channel model is one in which, when a vector $\mathbf{x}_k = [x_1, x_2, \ldots x_{N_{TX}}]^T$ is transmitted in subcarrier k, the received vector $\mathbf{y}_k = [y_1, y_2, \ldots y_{N_{RX}}]^T$ is modeled as shown in Equation (20-62).

$$\mathbf{y}_k = H_k \mathbf{x}_k + \mathbf{n} \qquad (20\text{-}62)$$

where

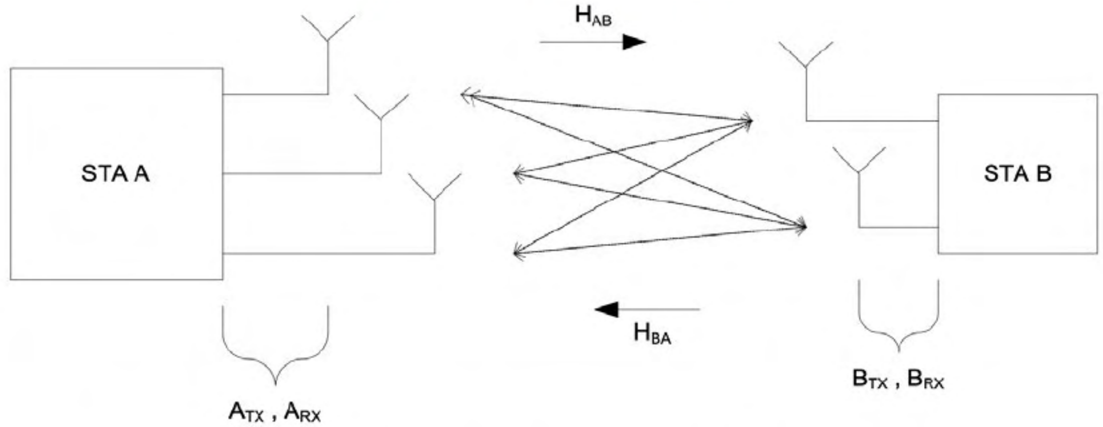
H_k	is channel matrix of dimensions $N_{RX} \times N_{TX}$
$\mathbf{n}$	is white (spatially and temporally) Gaussian noise as illustrated in Figure 20-14

When beamforming is used, the beamformer replaces $\mathbf{x}_k$, which in this case has $N_{STS} \leq N_{TX}$ elements, with $Q_k \mathbf{x}_k$, where Q_k has N_{TX} rows and N_{STS} columns, so that the received vector is as shown in Equation (20-63).

$$\mathbf{y}_k = H_k Q_k \mathbf{x}_k + \mathbf{n} \qquad (20\text{-}63)$$

The beamforming steering matrix that is computed (or updated) from a new channel measurement replaces the existing Q_k for the next beamformed data transmission. There are several methods of beamforming, differing in the way the beamformer acquires the knowledge of the channel matrices H_k and on whether the beamformer generates Q_k or the beamformee provides feedback information for the beamformer to generate Q_k.

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	 **Figure 20-14—Beamforming MIMO channel model (3x2 example)** Source: IEEE 802.11-2012 pages 1727-1728.

[redacted]

	IEEE Standard for Information technology— Telecommunications and information exchange between systems Local and metropolitan area networks— Specific requirements **Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications** **Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz** IEEE Computer Society Sponsored by the LAN/MAN Standards Committee IEEE 3 Park Avenue New York, NY 10016-5997 USA **IEEE Std 802.11ac™-2013** (Amendment to IEEE Std 802.11™-2012, as amended by IEEE Std 802.11ae™-2012, IEEE Std 802.11aa™-2012, and IEEE Std 802.11ad™-2012) Source: IEEE 802.11ac-2013 page 1.

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	22.3.11 SU-MIMO and DL-MU-MIMO Beamforming **22.3.11.1 General** SU-MIMO and DL-MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With SU-MIMO beamforming all space-time streams in the transmitted signal are intended for reception at a single STA. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs. For SU-MIMO beamforming, the steering matrix Q_k can be determined from the beamforming feedback matrix V_k that is sent back to the beamformer by the beamformee using the compressed beamforming feedback matrix format as defined in 20.3.12.3.6. The feedback report format is described in 8.4.1.48. For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u, $\boldsymbol{y}_{k,u} = [y_{k,0}, y_{k,1}, \ldots, y_{k,N_{RX_u}-1}]^T$, is shown in Equation (22-101), where $\boldsymbol{x}_k = [\boldsymbol{x}_{k,0}^T, \boldsymbol{x}_{k,1}^T, \ldots, \boldsymbol{x}_{k,N_{user}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{user} beamformees, with $\boldsymbol{x}_{k,u} = [x_{k,0}, x_{k,1}, \ldots, x_{k,N_{STS,u}-1}]^T$ being the transmit signal for beamformee u.

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	$$\boldsymbol{y}_{k,u} = \boldsymbol{H}_{k,u} \times [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}] \times \boldsymbol{x}_k + \boldsymbol{n} \quad (22\text{-}101)$$ where $\boldsymbol{H}_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX_u} \times N_{TX}$ N_{RX_u} is the number of receive antennas at beamformee u $Q_{k,u}$ is a steering matrix for beamformee u in subcarrier k with dimensions $N_{TX} \times N_{STS_u}$ N_{user} is the number of VHT MU PPDU recipients (see Table 22-6) $\boldsymbol{n}$ is a vector of additive noise and may include interference The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u}$, and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \ldots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 22.3.8.3.3 and 22.3.11.4). Source: IEEE 802.11ac-2013 pages 293-294. **19.3.4 Overview of the PPDU encoding process**

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	o) Determine whether 20 MHz or 40 MHz operation is to be used from the CH_BANDWIDTH parameter of the TXVECTOR. Specifically, when CH_BANDWIDTH is HT_CBW20 or NON_HT_CBW20, 20 MHz operation is to be used. When CH_BANDWIDTH is HT_CBW40 or NON_HT_CBW40, 40 MHz operation is to be used. For 20 MHz operation (with the exception of non-HT formats), insert four subcarriers as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers, N_{ST}, is 56. For 40 MHz operation (with the exception of MCS 32 and non-HT duplicate format), insert six subcarriers as pilots into positions –53, –25, –11, 11, 25, and 53, resulting in a total of $N_{ST} = 114$ subcarriers. See 19.3.11.11.5 for pilot locations when using MCS 32 and 19.3.11.12 for pilot locations when using non-HT duplicate format. The pilots are modulated using a pseudorandom cover sequence. Refer to 19.3.11.10 for details. For 40 MHz operation, apply a +90° phase shift to the complex value in each OFDM subcarrier with an index greater than 0, as described in 19.3.11.11.4, 19.3.11.11.5, and 19.3.11.12. p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation, $N_{TX} = N_{STS}$, and there is a one-to-one correspondence between space-time streams and transmit chains. In this case, the OFDM symbols associated with each space-time stream are also associated with the corresponding transmit chain. Otherwise, a spatial mapping matrix associated with each OFDM subcarrier, as indicated by the EXPANSION_MAT parameter of the TXVECTOR, is used to perform a linear transformation on the vector of N_{STS} complex numbers associated with each subcarrier in each OFDM symbol. This spatial mapping matrix maps the vector of N_{STS} complex numbers in each subcarrier into a vector of N_{TX} complex numbers in each subcarrier. The sequence of N_{ST} complex numbers associated with each transmit chain (where each of the N_{ST} complex numbers is taken from the same position in the N_{TX} vector of complex numbers across the N_{ST} subcarriers associated with an OFDM symbol) constitutes an OFDM symbol associated with the corresponding transmit chain. For details, see 19.3.11.11. Spatial mapping matrices may include cyclic shifts, as described in 19.3.11.11.2.

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	t) Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 19.3.7 for details. The transmit chains are connected to antenna elements according to ANTENNA_SET of the TXVECTOR if ASEL is applied. Source: IEEE Standard 802.11-2016 at 2349-2353.

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 4)</th></tr>
<tr><th>Claim 4</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>

21.3.11 SU-MIMO and DL-MU-MIMO Beamforming

21.3.11.1 General

SU-MIMO and DL-MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With SU-MIMO beamforming all space-time streams in the transmitted signal are intended for reception at a single STA. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs.

For SU-MIMO beamforming, the steering matrix Q_k can be determined from the beamforming feedback matrix V_k that is sent back to the beamformer by the beamformee using the compressed beamforming feedback matrix format as defined in 19.3.12.3.6. The feedback report format is described in 9.4.1.49.

For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u, $\boldsymbol{y}_{k,u} = [y_{k,0}, y_{k,1}, \ldots, y_{k,N_{RX_u}-1}]^T$, is shown in Equation (21-101), where $\boldsymbol{x}_k = [\boldsymbol{x}_{k,0}^T, \boldsymbol{x}_{k,1}^T, \ldots, \boldsymbol{x}_{k,N_{user}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{user} beamformees, with $\boldsymbol{x}_{k,u} = [x_{k,0}, x_{k,1}, \ldots, x_{k,N_{STS,u}-1}]^T$ being the transmit signal for beamformee u.

$$\boldsymbol{y}_{k,u} = \boldsymbol{H}_{k,u} \times [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}] \times \boldsymbol{x}_k + \boldsymbol{n} \qquad (21\text{-}101)$$

where

$\boldsymbol{H}_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX_u} \times N_{TX}$

</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 4)	
Claim 4	**Example Viasat Systems and Services**
	N_{RX_u} is the number of receive antennas at beamformee u $Q_{k,u}$ is a steering matrix for beamformee u in subcarrier k with dimensions $N_{TX} \times N_{STS_u}$ N_{user} is the number of VHT MU PPDU recipients (see Table 21-6) $\boldsymbol{n}$ is a vector of additive noise and may include interference The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u}$, and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \ldots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 21.3.8.3.3 and 21.3.11.4). Source: IEEE 802.11-2016 pages 2578-2579.

U.S. Patent No. 8,027,326 (Claim 18)	
Claim 18	**Example Viasat Systems and Services**
[18.pre]. A non-transitory computer-readable medium having instructions stored thereon, the instructions comprising:	To the extent this preamble is limiting, on information and belief, the Viasat Systems and Services include a non-transitory computer-readable medium having instructions stored thereon. On information and belief, the Viasat Systems and Services support Wi-Fi 802.11 ac/abgn, such as the Viasat Select Router.

[redacted]

U.S. Patent No. 8,027,326 (Claim 18)	
Claim 18	**Example Viasat Systems and Services**
	The Gen-2 equipment includes upgrades to the following: • **Antenna:** ViaSat's Gen-2 antenna supports the full Ka-band spectrum defined by the International Telecommunication Union (ITU), doubling useable satellite capacity and enabling the full range of capabilities on ViaSat's satellites. An upgraded Gen-2 Antenna Power Supply is designed to make use of ARINC 791 provisions for simple installation. • **Radome:** ViaSat optimized its Gen-2 radome and ARINC 791-compatible mounting plate for reduced weight and minimal signal distortion, enabling full performance on ViaSat's satellites while reducing fuel consumption. • **Modem:** ViaSat's Gen-2 modem is capable of supporting throughput levels of up to 1 Gigabit per second (Gbps), allowing airlines to make the most of the advanced capabilities expected from ViaSat's current and next-generation satellite platforms. • **Wireless Access Points (WAPs):** ViaSat's 802.11ac Wave 2 WAPs deliver higher speeds from the modem to each connected device on the aircraft by removing potential bottlenecks caused by the cabin design. • **On-Board Server:** ViaSat is enabling airlines to host more in-flight crew, ground crew and passenger-focused applications with its open platform server. ViaSat's future focused platform is backed by a powerful quad-core Intel CPU and 30 terabytes (TB) of solid-state storage, far exceeding the capabilities of other in-flight servers deployed today. Source: https://investors.viasat.com/news-releases/news-release-details/viasat-unveils-second-generation-mobility-equipment-deliver.

[redacted]

U.S. Patent No. 8,027,326 (Claim 18)	
Claim 18	**Example Viasat Systems and Services**
	Viasat Select Router Redefining the in-flight connectivity experience The Viasat Select Router, coupled with Viasat's latest generation satellite terminal, delivers a fully managed internet connectivity network inside the cabin that promises to deliver maximum speed and capabilities from Viasat's high-capacity satellite network. Source: https://www.viasat.com/content/dam/us-site/aviation/documents/Viasat_Select_Router-datasheet.pdf.

[redacted]

<table>
<tr><th colspan="2">U.S. Patent No. 8,027,326 (Claim 18)</th></tr>
<tr><th>Claim 18</th><th>Example Viasat Systems and Services</th></tr>
<tr><td></td><td>

<h3>Multi-link connections</h3>

The Viasat Select Router ("VSR") is a fully featured cabin connectivity management device that integrates the Viasat connectivity service with other available cabin connectivity on the aircraft. User traffic is routed automatically over the best available network and in the event of a service disruption, an alternate service is automatically selected to ensure continuous internet access.

Every VSR is equipped with an integral cellular modem that enables near global 4G LTE data service while the aircraft is on the ground. The data service can be used by passengers or crew, and is available to Viasat's technical support team for remote access to assist with equipment configuration, software updates, and other troubleshooting support, while the aircraft remains in the hangar.

The router incorporates an 802.11ac Wi-Fi access point for easy in-cabin wireless connectivity for passengers, crew and ground operations. Additional antennas can be added to ensure optimal signal strength inside the cabin as necessary.

Source: https://www.viasat.com/content/dam/us-site/aviation/documents/Viasat_Select_Router-datasheet.pdf.

SPECIFICATIONS

<table>
<tr><td>Size</td><td>1.75 in. H × 7.8 in. W × 5.5 in. D</td><td>Storage</td><td>1 TB (OS and applications)</td></tr>
<tr><td>Weight</td><td>3.9 lbs</td><td>Ethernet Ports</td><td>› 5 x 10/100/1000 bps Ethernet Ports (Switched)
› 1 x 10/100/1000 bps Ethernet Ports (Direct)
› 1 x 10/100/1000 bps Ethernet Ports (Front Panel)</td></tr>
<tr><td>Voltage</td><td>28VDC with 200ms Hold-up</td><td></td><td></td></tr>
<tr><td>Power</td><td>20W(typical); 30W (max)</td><td>ARINC 429</td><td>2x Rx Channels / 1x Tx Channel</td></tr>
<tr><td>Environment</td><td>Qualified to DO-160G</td><td>Cellular Modem</td><td>Integrated Global coverage 4G/LTE Advanced modem; 2x mini SIMs; 2x RF QMA connections</td></tr>
<tr><td>Processor</td><td>Intel E3845 4 Core processor, 1.5GHz</td><td>Wi-Fi</td><td>802.11 ac/abgn; 3x RF QMA connections</td></tr>
</table>

Source: https://www.viasat.com/content/dam/us-site/aviation/documents/Viasat_Select_Router-datasheet.pdf.

</td></tr>
</table>

[redacted]

U.S. Patent No. 8,027,326 (Claim 18)	
Claim 18	**Example Viasat Systems and Services**
	IEEE 802.11n™, or Wi-Fi 4, was introduced in 2009 to support the 2.4 GHz and 5GHz frequency bands, with up to 600 Mbit/s data rates, multiple channels within each frequency band, and other features. IEEE 802.11n data throughputs enabled the use of WLAN networks in place of wired networks, a significant feature enabling new use cases and reduced operational costs for end users and IT organizations. **IEEE 802.11ac™, or Wi-Fi 5**, was introduced in 2013 to support data rates at up to 3.5 Gbit/s, with still-greater bandwidth, additional channels, better modulation, and other features. It was the first Wi-Fi standard to enable the use of multiple input/multiple output (MIMO) technology so that multiple antennas could be used on both sending and receiving devices to reduce errors and boost speed. Source: https://standards.ieee.org/beyond-standards/the-evolution-of-wi-fi-technology-and-standards/. On information and belief, by bonding two 20 MHz channels together, the IEEE 802.11-2016 standard enables 40 MHz capable high throughput (HT) operation, which can support high data rates up to 600 Mb/s. *See* claim 1. On information and belief, IEEE 802.11ac infringes for the same reasons as 802.11n. *See* claim 1.
instructions to select at least a first channel and a second channel, wherein the first channel and the second channel are adjacent without any other channels therebetween, wherein the first channel and the second channel each have a plurality of data subcarriers, wherein the data subcarriers of the first channel and the data subcarriers of the second channel are separated by a frequency gap corresponding to one or more guard bands between the first and second channels;	On information and belief, the Viasat Systems and Services include a non-transitory computer-readable medium having instructions to select at least a first channel and a second channel, where the first channel and the second channel are adjacent without any other channels therebetween, where the first channel and the second channel each have a plurality of data subcarriers, and where the data subcarriers of the first channel and the data subcarriers of the second channel are separated by a frequency gap corresponding to one or more guard bands between the first and second channels. See claim 1 including claim limitation [1.a].

[redacted]

U.S. Patent No. 8,027,326 (Claim 18)	
Claim 18	**Example Viasat Systems and Services**
instructions to partially fill the frequency gap between the first channel and the second channel by adding one or more data subcarriers into the frequency gap such that the one or more guard bands are at least partially filled with at least some of the one or more data subcarriers using full spectral synthesis capability of a fast fourier transform or an inverse fast fourier transform;	On information and belief, the Viasat Systems and Services include a non-transitory computer-readable medium having instructions to partially fill the frequency gap between the first channel and the second channel by adding one or more data subcarriers into the frequency gap such that the one or more guard bands are at least partially filled with at least some of the one or more data subcarriers using full spectral synthesis capability of a fast fourier transform or an inverse fast fourier transform. See claim 1 including claim limitation [1.b].
instructions to combine the first channel and the second channel using channel bonding with orthogonal frequency division multiplexing (OFDM); and	On information and belief, the Viasat Systems and Services include a non-transitory computer-readable medium having instructions to combine the first channel and the second channel using channel bonding with orthogonal frequency division multiplexing (OFDM). See claim 1 including claim limitation [1.c].
instructions to transmit data subcarriers occupying the first channel, the second channel, and the frequency gap in parallel to a receiver.	On information and belief, the Viasat Systems and Services include a non-transitory computer-readable medium having instructions to transmit data subcarriers occupying the first channel, the second channel, and the frequency gap in parallel to a receiver. See claim 1 including claim limitation [1.d].